CERAMIC ABSTRACTS and THE BULLETIN

AMERICAN CERAMIC SOCIETY

NOVEMBER 15, 1942

MONTHLY PUBLICATION DEVOTED TO THE ARTS AND SCIENCES RELATED TO THE SILICATE INDUSTRIES

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After pre-heating, the broach is transferred to a high-temperature furnace of similar type. The difference between the control systems of the two is in the temperature detectors; the high-temperature furnace using three Rayotubes in place of thermocouples.

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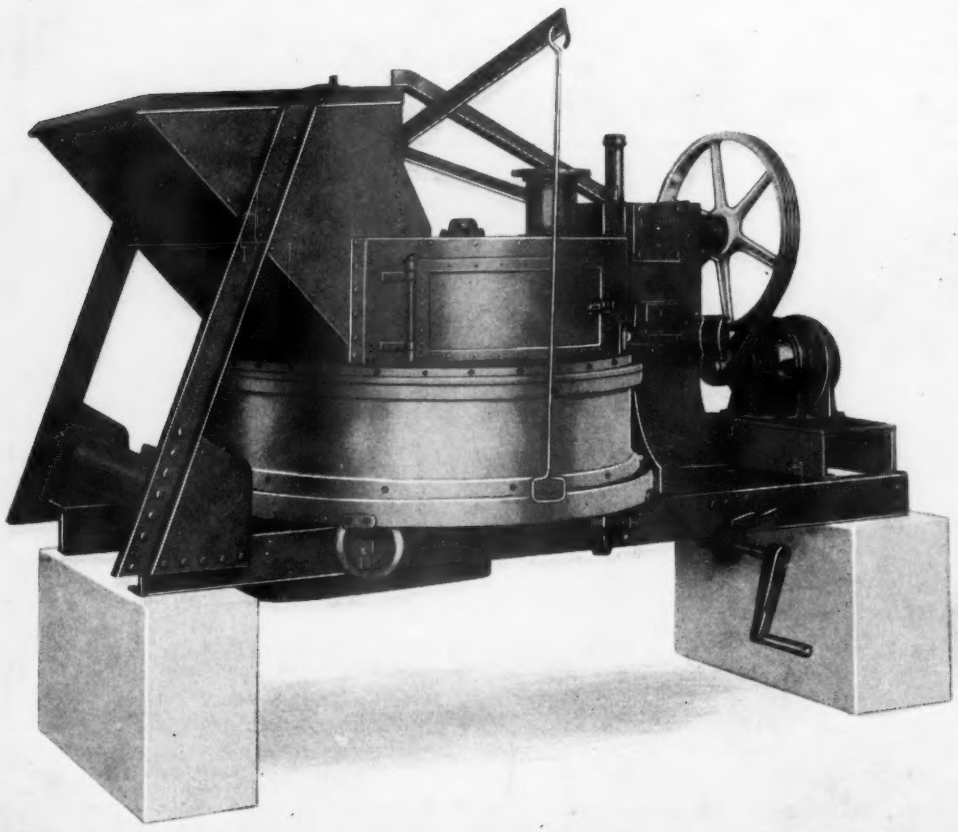

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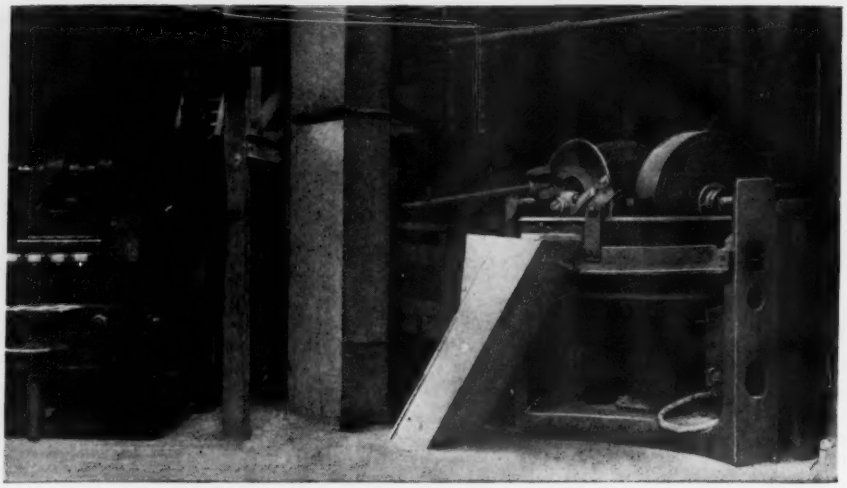

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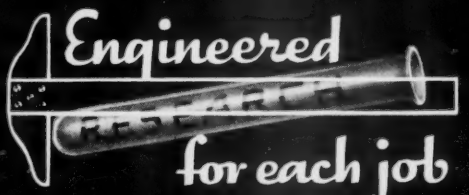

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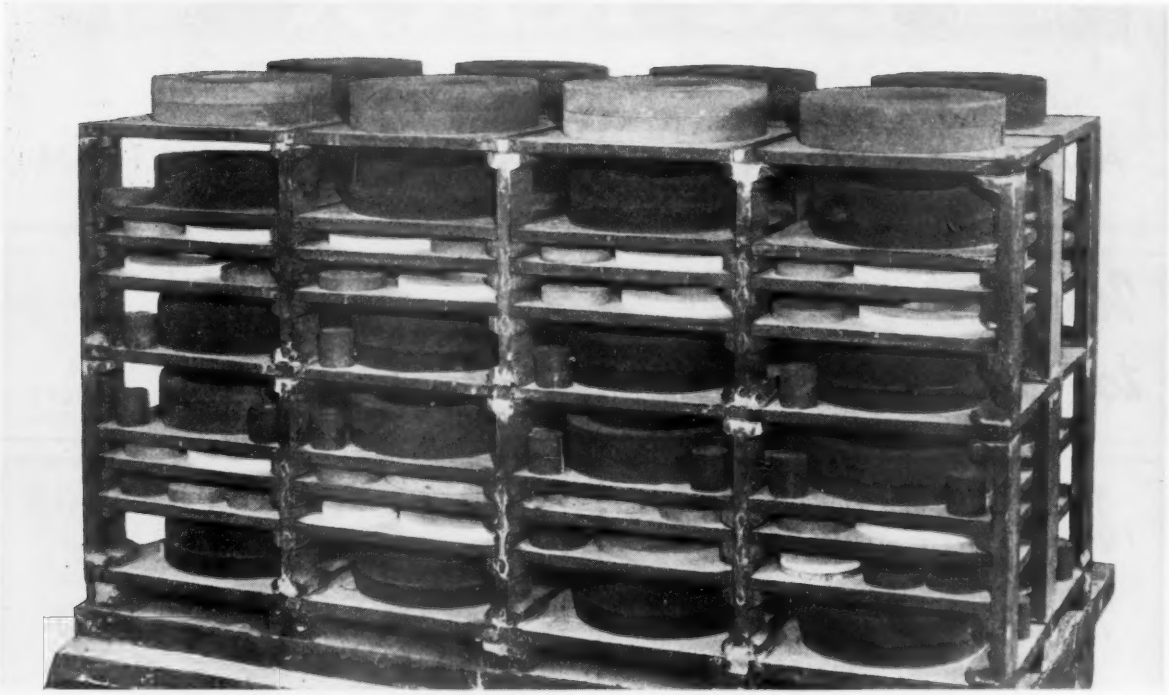

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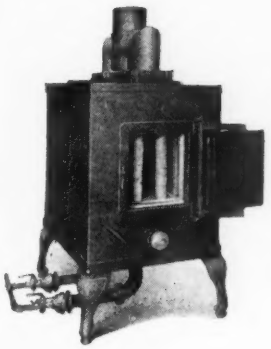

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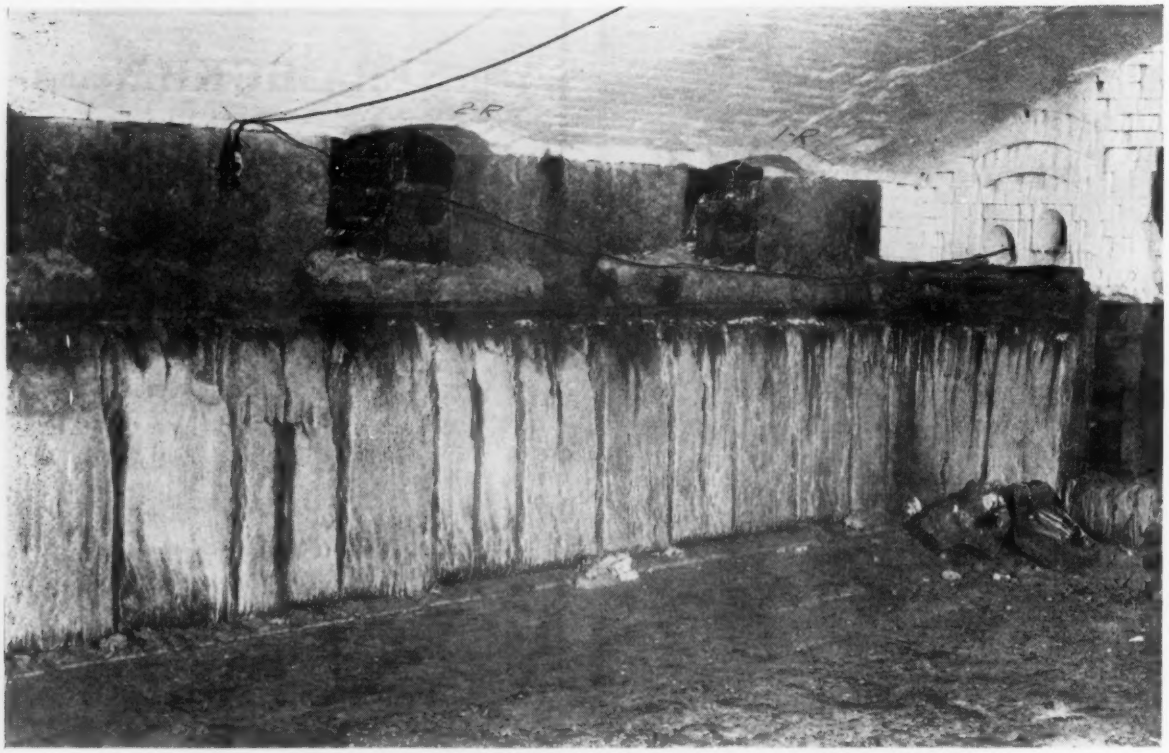

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	CAMPAIGN 1935-1937	CAMPAIGN 1937-1939	CAMPAIGN 1939-1942
Total Days of Life	708	710	1,100
Total Operating Days	556	456	835
Square Feet Melting Area	1,000	1,000	1,000
Total Glass Delivered (Tons)	76,446	62,638	122,200
Tons of Glass Melted Per Day (based on total life)	107.9	88.2	111.0
Tons of Glass Melted Per Day (based on operating days)	137.4	137.3	146.3
Square Feet Melting Area Per Ton of Glass (based on total life)	9.2	11.3	9.0
Square Feet Melting Area Per Ton of Glass (based on operating days)	7.2	7.2	6.8
Tons of Glass Per Square Foot of Melting Area Per Life of Tank	76.4	62.6	122.2

QUALITY ECONOMY ENDURANCE

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REFRACTORIES

CERAMIC ABSTRACTS

Compiled by

THE AMERICAN CERAMIC SOCIETY

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JOURNAL REFERENCE: The journal name appears in italics, followed by the volume (bold-faced), issue number (in brackets), page numbers, and year (in parentheses).

Vol. 21 November 15, 1942 No. 11

Abrasives

SEPARATE PUBLICATIONS

On the Grinding Line. Norton Co., Worcester, Mass. Reviewed in *Steel*, **110** [9] 116 (1942).—Hints on grinding are given for plants employing new grinding operators. E.D.M.

Grinders and Buffers. *Cincinnati Electrical Tool Co. Bull.*, No. 129-E, 2 pp.—General purpose grinders and buffers are listed.

PATENTS

Abrading machine. L. D. ALDERMAN (United Shoe Machinery Corp.). U. S. 2,295,622, Sept. 15, 1942 (July 25, 1940). E. W. STACEY (United Shoe Machinery Corp.). U. S. 2,295,695, Sept. 15, 1942 (Aug. 1, 1940).

Abrasive articles and their manufacture. NORTON GRINDING WHEEL CO., LTD. Brit. 546,805, Aug. 12, 1942 (Oct. 2, 1940).

Apparatus for burnishing shoulders of collapsible tubes. A. W. PAULL, SR., A. L. EDWARDS, AND W. T. DAVIS (Wheeling Stamping Co.). U. S. 2,298,067, Oct. 6, 1942 (Jan. 16, 1941).

Bonded abrasive bodies. A. C. WICKMAN, LTD., AND W. H. BATEMAN. Brit. 546,697, Aug. 6, 1942 (Jan. 24, 1941).

Brake shoe grinding machine and gauge. HJALMAR THOMASON. U. S. 2,295,061, Sept. 8, 1942 (Aug. 25, 1939).

Centerless grinding machine. J. E. BERGSTRÖM. U. S. 2,297,045, Sept. 29, 1942 (June 25, 1940).

Crankshaft-grinding machine. F. E. JOHNSON (Norton Co.). U. S. 2,297,654, Sept. 29, 1942 (Nov. 5, 1941).

Drill grinder. G. R. MORRIS. U. S. 2,295,265, Sept. 8, 1942 (April 19, 1941).

Facet-grinding attachment. HARRY KOUSIN. U. S. 2,297,306, Sept. 29, 1942 (July 26, 1941).

Grinder aligner. E. A. FUGLIE. U. S. 2,298,005, Oct. 6, 1942 (June 29, 1942).

Honing machine. C. A. FULMER. U. S. 2,297,953, Oct. 6, 1942 (Feb. 25, 1941).

Infeeding mechanism for grinding machines. A. F. GRAF AND W. T. SEPTANT (Cincinnati Grinders, Inc.). U. S. 2,295,342, Sept. 8, 1942 (Dec. 24, 1940).

Lapping machines. NEW CONVEYOR CO., LTD., AND G. AMERY. Brit. 546,958, Aug. 19, 1942 (June 13, 1941).

Machine for making abrasive disks. F. O. ALBERTSON (Albertson & Co., Inc.). U. S. 2,296,890, Sept. 29, 1942 (Nov. 25, 1938).

Manhole-grinding machine. A. C. ROHRDANZ. U. S. 2,297,074, Sept. 29, 1942 (March 17, 1941).

Means for sharpening bits. W. J. MOERLIN AND R. C. BERGGREN (Mine and Smelter Supply Co.). U. S. 2,298,018, Oct. 6, 1942 (July 10, 1939).

Means for trimming helical abrasive wheels. D. BROWN & SONS, LTD., AND W. A. TUPLIN. Brit. 547,184, Sept. 2, 1942 (Dec. 14, 1940).

Mechanisms and methods for trimming curved contours. L. MELLERSH-JACKSON (Gear Grinding Machine Co.). Brit. 547,233, Sept. 2, 1942 (Feb. 18, 1941).

Resilient mounting for abrasive wheels. A. W. MALL. U. S. 2,295,282, Sept. 8, 1942 (May 31, 1940).

Roll-grinding machine. A. W. WIGGLESWORTH (Hill-Clarke Machinery Co.). U. S. 2,297,093, Sept. 29, 1942 (Oct. 4, 1940).

Sharpener for cloth-cutting machines. J. B. GURY, JR. (J. B. Gury Mfg. Co.). U. S. 2,295,654, Sept. 15, 1942 (March 31, 1941).

Sharpening device for the rotating sickle knife of cigarette rod machines. P. L. GRAUPNER (vested in the Alien Property Custodian). U. S. 2,297,468, Sept. 29, 1942 (May 28, 1940).

Stop mechanism for grinding machines. R. H. MUSTONEN (Gear Grinding Machine Co.). U. S. 2,296,731, Sept. 22, 1942 (March 12, 1941).

Surface grinding machine. H. A. SILVEN (Norton Co.). U. S. 296,064, Sept. 15, 1942 (Oct. 14, 1941).

Terrazzo grinder. H. J. POND AND C. O. LARSON (Advance Machine Co., Inc.). U. S. 2,298,228, Oct. 6, 1942 (July 20, 1940).

Art and Archeology

Argument for technology of ceramic design. KENNETH E. SMITH AND PAUL E. COX. *Bull. Amer. Ceram. Soc.*, **21** [9] 190–91 (1942).

Ceramic materials in artistic form. J. GRELL. *Keram. Rundschau*, **46** [37] 413–23 (1938).—The interest in the creative and artistic aspects of all types of ceramic ware decreased when the industry became mechanized, but interest in both machine-made and hand-produced art or utility ware is returning. Illustrated. M.V.C.

Glazing of pottery. A. BERNARD HOLLOWOOD. *Ind. Chemist*, **18**, 4–6 (1942).—Even vitreous pottery bodies are porous, those with a conchoidal glassy fracture being able to absorb $1^1/_2$% water; this necessitates coating the ware with an impervious layer of glass. In the earliest method, powdered lead ore was used, but this was superseded by salt glazing. NaCl is shoveled into the kiln at about 1300°C.; this decomposes into HCl and Na_2O, and the sodium oxide forms a refractory glass with the earthenware silicate. It is used for drainpipes, etc.; it is cheap and resistant to all but the strongest chemicals, but the surface is pitted. Modern glazes are either raw or fritted and are applied in liquid form. The soluble ingredients are fritted, and the frit is mixed with the insoluble ingredients, as a wholly fritted glaze suspends poorly in water. Requirements for a good pottery glaze are given. For lead glazes, care must be taken that the lead compounds are obtained in a form which cannot be attacked by acid foods. The fusing point depends on the nature of the materials and their proportions. An excessively fusible glaze is absorbed or drains off; excess silica causes devitrification. If the glaze does not have the same coefficient of expansion as the body, one or the other will crack. In fine ware it is practical to alter the body as well as the glaze. A glaze for kitchen utensils should withstand boiling in strong vinegar. The constituents of a glaze may include potash, soda, lime, lead oxide, magnesia, baryta, silica, and coloring materials such as nickel, iron, copper, cobalt, chromium, tin, antimony, cadmium, titanium, and uranium. Borax, boracic acid, and silicates are the main ingredients of leadless glaze frits. A leadless glaze is less brilliant and more easily affected by weather than the lead glaze, but beautiful effects are possible. Turquoise blues can be obtained only in highly alkaline leadless glazes free from boric acid. Colorless glazes can be rendered milk-white with finely divided tin oxide. Crystalline glazes are produced in high-temperature kilns through the deposition of certain silicates as crystals. Most glazes will crystallize if loaded with sufficient zinc oxide. Those with a high boric acid content tend to be opalescent. Transmutation glazes such as *flambé*, peach bloom, and pigeon's-blood are obtained with copper oxide in a reducing atmosphere. At temperatures higher than 1200°C., the volatility of lead oxide is so great that the material cannot be used as a flux. See "Ceramic . . .," *Ceram. Abs.*, **21** [4] 85 (1942). E.D.M.

Investigation of the 19th century "pot shops" of Ohio's Hocking and Vinton Counties. JEAN COCHRAN. *Bull. Amer. Ceram. Soc.*, **21** [9] 188–89 (1942).

New understanding of color. HOWARD KETCHAM. *Enamelist*, **19** [7] 22–26, 53–54 (1942); see "New . . .," *Bull. Amer. Ceram. Soc.*, **21** [3] 45 (1942). L.E.T.

Origin of ceramics in Alsace. AUGUST HERBORTH. *Keram. Rundschau*, **49** [16] 157–60; [17] 169–71 (1941).—Discoveries in ancient tombs in Alsace indicate that pottery existed there 4000 to 5000 years before the Christian Era because of the extensive rich clay deposits in this district. The native art of the Franks and Alemanni was later influenced by the Romans, but it was at its height during the metal age, and numerous specimens still exist in the museums of the district. At present, the principal pottery sites are Sufflenheim and Betschdorf. The clays are especially suitable for engobes. A very pure variety is that of Haguenau; it is rich in lime and very plastic and is used particularly for faience. To increase the resistance to temperature changes of refractories made of Sufflenheim clay, chamotte is added; additions of kaolin reduce shrinkage at high temperatures. Descriptions and illustrations of old operating methods are given, and the recent revival of the ceramic industry in Alsace is discussed. M.HA.

Original models for ceramic paintings and sculpture. MICHAEL BIRKENBIHL. *Keram. Rundschau*, **46** [46] 537–41; [47] 551–53; [48] 561–64; [49] 575–76; [50] 585–87; [51] 594–99 (1938).—B. presents a study of faience, porcelain, and ceramic paintings and ornamentation and the original works of art from which they were derived. The original paintings and engravings were copied by ceramic artists in a personalized manner and according to the ability and character of the artists. Sometimes only one figure from the original work of art was used, alone or in an original group composition. The nature of the medium and the form of the piece often necessitated changes in the original. The motifs of German faience painters were conditioned by the mentality of the times. Chinese porcelain furnished models which were copied profusely by Europeans. Until the 14th century, only monochrome porcelain in delicate colors was made in China; not until the 15th century did the Chinese learn about colors for painting porcelain (the Mohammedan blue among others), supposedly from the Arabs. As early as 1520, the blue-painted porcelain of East Asia was imported to Europe. In the 17th century, the Chinese used four or five colors, applied over the glaze; a high degree of perfection was reached when one piece would pass through as many as 70 hands, each artist applying one figure or one outline drawing, a bird or a flower, etc. The taste of the Europeans appeared crude and barbaric to the Chinese, whose hard pure white porcelain with its clear ring filled early European potters with wonder. Events of the time started certain trends in faience and porcelain painting. The century of the Reformation and the Thirty Years' War caused a special interest in biblical subjects which persisted until the middle of the 18th century. Social and political forces aroused considerable interest in heraldry as early as 1520. Besides coats of arms, emblems and symbols with elaborate mottos were greatly favored. Landscapes with ruins occupied an important place in faience and glass painting and extended as far back as the 15th century. Antique statues, Roman ruins, and melancholy and weathered ruins were copied from the engravings and paintings of famous artists of the time. The painting of flowers in all forms was the most important subject of all ceramic painting, and botany and ornithology furnished many subjects for painters of some regions. Battle scenes and military subjects were popular with the great baroque painters of the 17th century and furnished models for porcelain, faience, and glass ornamentation. The battle with the Turks before Vienna in 1683 made a great impression on the people of the time, and scenes of the battle and Turkish figures and subjects in general were incorporated into art, including ceramic paintings. Seventeenth-century painters again took up the painting of animal life and hunting scenes, the latter being very popular in the rococo period. The influence on ceramic art of the three painters most representative of the refined graces of rococo living (Boucher, Watteau, and Fragonard) is analyzed. Ceramic artists of later periods were furnished models by characters from Italian comedy, antique mythology, the books of Goethe, Lessing, and others, folk life, and tradespeople. The creative art of porcelain making and painting began to decline as early as 1780; in spite of the subsequent introduction of much that was new, slavish copying replaced original work more and more. The period of the Empire evinced a great fondness for portrait painting, especially on coffee services. Collections of engravings and paintings of different periods used as source material for ceramic painters are mentioned. Styles and free compositions invented by the greatest creative ceramic artists are characterized, and museum pieces from the various periods are discussed. M.V.C.

PATENTS

Design for combined bowl and plate. S. E. PARKER. U. S. 133,703, Sept. 8, 1942 (May 7, 1942).

Design for a hurricane lamp adapter for candlesticks. C. J. UHRMANN (Imperial Glass Corp.). U. S. 133,955 and 133,956, Sept. 29, 1942 (May 28, 1942).

Cements

Production of gypsum plaster by wet methods. E. P. SCHOCH AND W. A. CUNNINGHAM. *Trans. Amer. Inst. Chem. Engrs.*, **37**, 1–18 (1941).—Calcium sulfate hemihydrates produced by heating gypsum in various aqueous solutions have distinctive crystalline form and physical properties, but few of them make good plaster. That produced in magnesium sulfate solution is an excellent plaster of Paris and has tensile and compressive strengths of approximately 600 and 4600 lb. per sq. in., respectively; these strengths can be increased 50% by moderate grinding. The process has been tested by pilot-plant operation, and brief descriptions of the pilot-plant construction and operating characteristics are presented. Economic studies indicate that the commercial production of a high-strength gypsum plaster by this method is entirely feasible. 8 references. E.D.M.

Enamel

Acid resistance of enamel—a new method for its determination. GERHARD SCHMIDT. *Chem. Fabrik*, **13** [3] 49–54 (1940); see "Determination . . . ," *Ceram. Abs.*, **20** [1] 8 (1941). W.H.H.

Chipping of porcelain enamel coatings. ANON. *Product Eng.*, **13** [5] 273 (1942).—Excessively thick porcelain enamel coatings chip quite easily during the assembly of enameled parts; assembly losses are almost seven times greater on parts with coatings over 0.021 in. thick than on parts with coatings less than 0.018 in. thick. Stresses caused by drawing up bolts do not cause chipping. See "Reduction . . . ," *Ceram. Abs.*, **21** [1] 6 (1942). M.HA.

Consistency of boron-free enamel slips. F. BENESCHOVSKY. *Keram. Rundschau*, **49** [15] 147–49 (1941).—Systematic experiments were made to determine the behavior of boron-free enamel slips, especially the consistency and mobility required to give as satisfactory results as borax-containing slips. The consistency measurements were made with the Bingham plastometer (*Jour. Amer. Ceram. Soc.*, **21** [2] 66–68 (1938)). The tests showed that the consistency and method of application of boron-free enamel slips are quite different. In boron-containing slips the salts dissolved in the mill water have a decided effect on consistency, and all factors influencing this solubility also affect the consistency, but boron-free glazes do not seem to be affected to the same extent. It is necessary to work with considerably higher densities in boron-free slips and to adjust the consistency and mobility in both the mill and the coating with a previously determined amount of setting agent. The good mobility of boron-containing slips is, however, not obtainable. The best setting agent is bentonite; calcined magnesia has much less effect. Unfortunately, bentonite reduces the mobility to such an extent that clay must always be mixed with the bentonite. The tests of different slips and setting agents are described. M.HA.

Effectiveness of opacifiers in glasses, glazes, and enamels. F. H. ZSCHACKE. *Keram. Rundschau*, **49** [20] 197–201 (1941).—Three kinds of opacification in glasses and enamels are distinguished: (1) Opacification by small particles precipitated from the melt during solidification, due to devitrification, which have a different refractive index from that of the melt. (2) Disintegration phenomena due to the reduced solubility of certain constituents in the molten glass at low temperatures. These precipitations occur mostly in the shape of minute glass drops. In this class belongs the opacification by phosphates and arsenates in lead oxide-rich glasses. (3) Opacification caused by finely distributed glass bubbles. A fourth type of opacification is caused by undissolved constituents, with a higher refractive index, embedded in the glass mass. These are as a rule added as mill opacifiers to the frit and are seldom used in the opaque glass. In glazes, only the first and fourth types of opacification are employed. The effectiveness of various opacifiers was investigated with a glass whose principal composition was 58.70 SiO_2, 29 PbO, 10 K_2O, 2 Na_2O, 0.30 As_2O_3, and, in two modifications, 54.20 SiO_2 and either 4.50 Al_2O_3 or B_2O_3 to find the influence of alumina and boric acid on the opacifier. The opacifiers used were tin oxide, zirconium dioxide, antimony trioxide, arsenic trioxide, and fluorides. Tin oxide in an amount of 0.5% causes opacification when the melt is reheated to 850°C., and 2% tin oxide causes a deep opacity. Tin oxide is very soluble in boron-containing glasses at 850°, and heating to 1300°C. and subsequent rapid cooling does not cause pronounced opacity of the principal glass; the B-containing glasses do not therefore become opaque. The opacification imparted by zirconium dioxide is much less than that imparted by tin oxide; Al_2O_3 and B_2O_3 reduce opacification. Lead oxide- and boric acid-containing glasses remain clear even up to 20% ZrO_2, as B_2O_3 can dissolve considerable amounts of ZrO_2. Glasses with ZrO_2 are very hard. Antimony trioxide also produces a hard glass, but its opacifying effect is slight, as it is very soluble in the glass used. The principal glass and the Al_2O_3 modification show the greatest opacification, while the B-containing modification shows the least opacity and has the greatest solubility for Sb. A yellow coloration which sometimes occurs was not observed in the enamels. In Pb-containing glasses, the strongest opacifying effect was shown by arsenic trioxide which is reinforced by boric acid and by alumina; the opacification has a fine deep color. If heated to 1300° and quickly cooled, the glasses lose their opacity entirely or, in Al_2O_3 glasses, retain it only to a small extent; glasses heated to 850° show a considerably deepened opacity. The opacifying action of sodium fluosilicate is increased by the addition of alumina but is greatly reduced by boric acid. Reheating of a nonopacified melt to 850° opacifies the glass, as the fluoride is precipitated; when the glass is heated to 1300° and rapidly cooled, the opacity again disappears. 15 references. M.HA.

Operating a porcelain enamel plant at peak production. ANON. *Steel*, **110** [20] 108; [22] 86, 107–10 (1942).—Maintenance and equipment are considered under the headings: personnel, safety training, training of new employees, processing and control, and chemical and physical control. Some of the difficulties to be expected from new workers and lower grades of material are discussed. For reclaiming large and rigid shapes, a new method of cleaning known as "vapor blasting" is available, in which water is used as a medium for carrying sand at 60 lb. per sq. in. Plants working 24 hr. a day are advised to work out a program of maintenance whereby each piece of equipment is shut down for the shortest possible time at regular intervals for a thorough checkup; in this way breakdowns will be minimized. E.D.M.

Problems of the users of vitreous enameled ware. ANON. *Gas Jour.*, **224**, 645 (1938).—In a symposium by the Southern Section of the Institute of Vitreous Enamellers, the desirability from the viewpoint of the gas industry of a national code of enamelware tests was dealt with. Of the articles rejected, 99% had chipped because the enamel was too thickly applied. The standard of acid resistance required to withstand the products of combustion in the gas cooker was high, being equivalent to resistance to 10% oxalic acid solution for 30 min. Vitreous enamel was not an ideal material. It was unsuitable

for grates and the grill pan, although it was customary to enamel the latter. L.R.B.

Protective materials for casting molds. J. MEHRTENS. *Metallwirtschaft*, **20** [11] 269–70 (1941).—Mold surfaces must be coated with a protective substance to insure clean surfaces on the casting and to prevent burning of the metal into the mold. For most metals, the basic material for the protective coating consists of graphite (natural or synthetic), mixed according to purpose with ground clay, charcoal, coke powder, and sometimes bituminous coal dust. For die-casting and centrifugal-casting methods, a graphite-oil suspension is advisable. Chill molds for magnesium castings are coated with an aqueous solution of whiting with an addition of boric acid (80 gm. whiting and 6 gm. boric acid in 1 liter of water); this is sprayed on at a temperature of 250°C. Other coatings are made up of petroleum, rapeseed oil, etc. M.HA.

Suggested method for neutralizing waste pickling acid effluents. F. SMITH. *Chem. & Ind.*, **61** [6] 68–69 (1942).—The acid wastes from pickling baths of enamel plants may be treated with waste sludge from a lime-soda water-softening plant. The 7.5%, by volume, sulfuric acid solution is diluted with an equal volume of water. Soda ash is added to facilitate the neutralization. For 100 cc. of 7.5% acid solution, 35 to 39 gm. of soda ash are required for the reaction. R.H.B.

PATENTS

Design for cooker pot. ALFONS BARNSTEINER (Westinghouse Electric & Mfg. Co.). U. S. 133,936, Sept. 29, 1942 (Aug. 19, 1941).

Manufacture of vitreous enameled articles. H. J. FRALISH (Western Electric Co., Inc.). U. S. 2,295,945, Sept. 15, 1942 (Jan. 24, 1940).

Vitreous enamel containing zirconium and process for preparing. MAXIME PÂQUET. U. S. 2,294,931, Sept. 8, 1942 (May 26, 1939).—A process of making an enamel having a zirconium-containing opacifying constituent, particularly adapted for application to ceramic ware, which comprises first preparing a frit containing about 40 to 55 silica, about 4.5 to 10 alumina, about 8 to 12 boric anhydride, and about 8 to 10% zirconia, the amount of alkali metal compounds in the frit being not substantially above 7.4%, figured as Na_2O, and which frit is at least nearly saturated with zirconia, and thereafter milling this zirconium-containing frit while in the presence of an opacifying agent containing a zirconium compound.

Glass

Adhesion and adhesives with special reference to anti-scatter treatments for windows: I, Adhesion and adhesives. B. BUTTERWORTH. *Chem. & Ind.*, **61** [32] 339–41 (1942).—A general discussion is presented of (1) vegetable gums, (2) starch and dextrin adhesives, (3) animal glues and gelatin, (4) fish glues, (5) casein cements, (6) cellulose adhesives, (7) synthetic resin adhesives, (8) varnish adhesives, and (9) miscellaneous adhesives, such as rubber latex, sodium silicate, shellac, rosin, lime sucrate, and alkali resinates. **II, Properties required in adhesives for window protection.** *Ibid.*, [33] 350–51.—An adhesive for sticking either textile fabrics or transparent films to window glass to prevent its being scattered by blast should have the following properties: (1) It should be compatible with both the glass and the protective material and give a sufficiently strong bond. (2) It should have no effect on the strength of the fabric or film. (3) It should not injure the glass. (4) It should not become brittle or flake away from the glass on exposure. (5) It should not be unduly weakened by exposure to a very humid atmosphere. (6) It should not encourage the growth of molds. Each requirement is discussed in detail. R.H.B.

Alumina-silica relationship in glass. HURD W. SAFFORD AND ALEXANDER SILVERMAN. Presented at meeting of Glass Division, American Ceramic Society, Conneaut Lake Park, Pa., Sept., 1941; abstracted in *Ceram. Ind.*, **37** [4] 48 (1941). H.T.

Brandenburg-Prussian glassware. J. GR. *Keram. Rundschau*, **46** [49] 569–71 (1938).—The most brilliant period of the early Brandenburg-Prussian state art glass factories was during the 17th century and the first half of the 18th century. Some of the best pieces of art glass of the period still in existence are shown and characterized. M.V.C.

Chemical durability of glass: I, Relation between the amount of alkali extracted with water and the duration of dissolution. TARO MORIYA. *Jour. Soc. Chem. Ind. Japan*, **43** [11] 403B (1940) (in English).—The relation between the amount of alkali extracted with water and the time of extraction is expressed by the empirical equation $S = at + b(1 - e^{-ct})$, where S is the amount of alkali extracted, t is the time, and a, b, and c are constants. The theoretical equation is of the same form. The constant c depends on the coefficient a, which is determined by the decrease in the number of alkali atoms on the glass surface during the extraction. **II, Relation between the amount of alkali extracted with water and temperature.** *Ibid.*, p. 404B.—Using powdered glass, measurements were made of the amount of alkali extracted at various temperatures. Theoretically, $\log S = f + \frac{g}{T}$, where T is the absolute temperature, f is a constant depending on the size of sample, extraction time, etc., and g is a constant depending on the dissolution energy of the alkali atom. The relation between $\log S$ and $1/T$ over the temperature range investigated may be closely represented by two straight lines meeting at a point which may be called the transition temperature for chemical durability, i.e., 68°C. for simple alkali silicate glass and 62°C. for simple borosilicate glass. The value of the dissolution energy of the alkali for each glass is derived from the slope of the log S-$1/T$ curve. For any glass, the value of the dissolution energy obtained at temperatures above the transition point is different from that found for lower temperatures. For simple alkali silicate glass, the value of the dissolution energy decreases with increasing silica content; for simple borosilicate glass, the value decreases with increase in B_2O_3. W.H.H.

Commercial use of scientific data with special reference to illuminating glassware. S. ENGLISH. *Jour. Soc. Glass Tech.*, **26** [114] 62–81T (1942).—Illuminating glassware must be (*a*) practicable from the manufacturing point of view, (*b*) technically correct from the illuminating point of view, and (*c*) artistically correct. The use of completely diffusing opal glass in conjunction with metal filament lamps is discussed. From a compilation of experimental data, certain generalities are known: (1) The percentage transmission of opal glasses is always higher for directed light than for diffused light (2 to 5% increase). (2) The proportion absorbed is always less for directed light than for diffused light by approximately 1 to 5%. (3) The proportion reflected is generally less for directed light than for diffused light. E. emphasizes the need for continued research and the industrial utilization of the results from such experimentation. R.H.B.

Decay of vibration phenomena of glass bars. JOE G. MCCANN. *Jour. Amer. Ceram. Soc.*, **25** [14] 409–13 (Oct., 1942).—4 references, 7 figures.

Effect of applied ceramic color on the strength of bottles. J. E. ABLARD. Presented at Seventh Conference on Glass Problems, Urbana, Ill., Nov., 1941; abstracted in *Ceram. Ind.*, **37** [6] 40, 80 (1941). H.T.

Effect of iron oxide on properties of soda-dolomite lime-silica glass. OWENS-ILLINOIS GLASS CO. GENERAL RESEARCH LABORATORY STAFF. *Jour. Amer. Ceram. Soc.*, **25** [14] 401–408 (Oct., 1942).—19 figures.

Electrical glass insulation. LONDON ELECTRIC WIRE CO. AND SMITHS, LTD. *Jour. Sci. Instruments*, **18** [10] 206–207 (1941).—Lewcoglass, glass-insulated wire, is now available in the U. S. A special alkali-free glass is drawn into fibers about 0.00025 in. in diameter which are made into yarn for wire coverings. The fiber is applied to wire

in a manner similar to that in which cotton and silk are applied; it is then given a special bonding treatment which increases its mechanical strength. Its dielectric strength is comparable to that of dry cotton and superior to that of asbestos. Its insulation resistance is extremely good, and a figure 50 times that of asbestos at 98% relative humidity has been obtained. Its thermal conductivity is comparable to that of silk, cotton, or paper and better than that of asbestos. G.A.K.

Elimination of batch dust. C. T. FRAZIER. Presented at Seventh Conference on Glass Problems, Urbana, Ill., Nov., 1941; abstracted in *Ceram. Ind.*, **37** [6] 36–37 (1941). H.T.

Fields of application and manufacture of highly reflective surfaces of aluminum. H. VON KLÜBER. *Metallwirtschaft*, **20** [12] 295–97 (1941).—Mirrors made by depositing a coating of Al in a high vacuum on glass, quartz, or a metal base have proved to be superior to silver mirrors and are now used particularly for astronomical instruments. The method of producing Al layers devised by Strong and Gaviola (*Ceram. Abs.*, **16** [11] 344–45 (1937)) is described, and it is pointed out that this method permits changing the original curvature of the mirror by depositing the Al in different thickness, e.g., changing a spherical mirror into a parabolic mirror. The reflectivity of such evaporated Al layers is 90% or greater in the whole visible wave range, while the least reflecting metals do not give more than 60%; this high reflectivity extends far into the ultraviolet. Aluminized concave gratings can be used without any glass optics in the ultraviolet range for which other mirrors could not be used. M.HA.

Flashed glasses. W. H. D. *Diamant*, **63** [10] 70 (1941).—The manufacture of a flashed glass requires similar thermal-expansion coefficients for both glasses to prevent spalling or cracking. The flashing of an ordinary sulfate glass with opal glass is somewhat difficult in this respect. A successful composition for the base glass consists of 480 sand, 178 lime, 183 sulfate, 12.75 coke, and 31 kgm. soda; the opal batch, which should melt in 5 hr., is made up of 45 sand, 8.5 soda, 3 potash, 4 cryolite, 10 feldspar, and 4.5 kgm. fluorspar and 200 gm. manganese oxide. The furnace must have a very uniform temperature to prevent burning of the opacifier. A red-flashed glass batch consists of 100 kgm. sand, 18 parts soda, 16 parts potash, 4 parts borax, 10 parts limestone, 2 parts tin ash, 4 parts cuprous oxide, 1.5 kgm. iron oxide, and 1.5 kgm. manganese oxide for an opal base glass of 100 sand, 26 soda, 10 limestone, 18 feldspar, 8 cryolite, and 8 parts fluorspar with the necessary amount of nickel oxide as decolorizer. The furnace should be very hot. A light-green or aquamarine flash for an opal glass of 96 sand, 14 potash, 16 soda, 16 feldspar, 11 fluorspar, 10 cryolite, and 2 parts zinc oxide consists of 85 sand, 20 soda, 10 potash, and 15 parts marble with 2.5 kgm. copper sulfate and 75 gm. cobalt oxide for light aquamarine and 1.5 kgm. potassium chromate and 2.5 kgm. copper oxide for light green; for Saxon blue 5.5 kgm. copper oxide and 50 gm. cobalt oxide and for green 3.5 kgm. barium chromate and 1 kgm. potassium chromate are added. A golden iridescence on a hollow glass is produced by a thin inner flashing which has been colored yellow by silver and an outer layer of nacre glass, opal glass, or crystal. The silver glass is made up of 100 sand, 80 red lead, 10 borax, 30 potash, and $^1/_3$ part silver oxide. M.HA.

Fluorescence of glass. WOLDEMAR A. WEYL. *Ind. Eng. Chem.*, **34** [9] 1035–41 (1942).—W. suggests a classification of fluorescent glasses in which they are arranged according to the role played by the vitreous phase in producing fluorescence: (1) fluorescent enamels containing crystalline phosphors (Lenard type), (2) fluorescent glasses containing crystalline residues on which the activator is adsorbed (Fischer type), (3) fluorescent glasses containing atoms or molecules in an "energetically isolated" state, and (4) glasses containing cations or anionic groups as fluorescence centers. The quenching of fluorescence in glass is discussed; it may be due either to heat, concentration, or foreign atoms. Illustrated. F.G.H.

Fluorine compounds as opacifying and clearing agents in the glass industry. F. H. ZSCHACKE. *Keram. Rundschau*, **47** [52] 547–49 (1939).—Although fluorine is used chiefly as an opacifier, it can also, under certain conditions, act as a clearing agent. While fluorspar and cryolite are the usual opacifiers, sodium fluosilicate has been used advantageously; it has the greatest F content and disintegrates at comparatively low temperatures (in silicotetrafluoride and sodium fluoride). The action of sodium fluosilicate is greatly improved by additions of oxides of zinc, lead, and antimony and also of barium and calcium. Alumina is not suitable and, in greater amounts, is even harmful. Batches for (I) glass for lamp screens, (II) glass for blowing, (III) glass for salve jars, (IV) milk glass for bottles and beakers, and (V) Albatrin glass are given in the following table:

Raw material	I	II	III	IV	V
Sand	100	100	100	100	100
Soda	3	15	10	22	18
Potash	12	8	14	6	5
Lime	16	10			
Sodium fluosilicate	12	10	10	12	10
Zinc oxide	6	4	3	3	5
Red lead	5		2	2	2
Barium carbonate		3	6		
Barium nitrate			2		2
Fluorspar		3	8	8	5
Feldspar			12	15	15
Antimony oxide				1	
Borax					2

The easy disintegration of the fluosilicate makes it important as a clarifier; it possesses all properties which otherwise can be obtained only by mixing other clarifiers, e.g., arsenic and saltpeter, or by using barium nitrate. The clarifying action is of special importance in colored glasses melted with coloring agents which cannot withstand oxidation agents, e.g., in brown glass melted on a sulfidic base, the coloring agent in which (iron sulfide) is completely destroyed by oxygen, and in green glasses, regardless of the base on which they are melted. The amount of sodium fluosilicate required for clarifying and decoloration is about 1 to 4 kgm. for 100 kgm. sand; this depends on the glass composition and the furnace operation and should be determined in each individual case. Fluorspar would have to be added in amounts of 2 to 5 kgm. per 100 kgm. sand, but its action is greatly inferior to that of sodium fluosilicate. M.HA.

Front-view mirrors. BRUNO SCHWEIG. *Ind. Chemist*, **18** [208] 173–74, 177 (1942).—Most mirrors utilize reflection from metal surfaces, and, for the best work, these are laid on glass, usually on the back where they are protected by varnish, paint, etc. These have two disadvantages from a scientific viewpoint: (1) both the front and the back of the glass give reflections, destroying clearness and distinctness of the image, and (2) the light has to travel twice through the thickness of the glass, losing strength and possibly changing color. For front-view mirrors, only Ag, Al, and Rh on glass have been considered. Silver does not adhere well enough to withstand repeated cleaning and tarnishes quickly. Plating the silver with rhodium has not so far proved successful. Up to the present, the best surface mirrors for scientific purposes have been obtained with aluminum, but their production requires very skillful technique. The Al is vaporized in a vacuum and deposits on the glass. Reflection is 90 to 94%, and the adhesion is good. Al is very resistant to atmospheric attack, and there is no large variation in the reflection of the different wave lengths. The 200-in. disk for Mount Palomar has an Al reflecting surface. Rhodium is deposited similarly to aluminum. Reflection is not more than 80%, but it is practically the same over the whole visible spectrum; the adhesion of the film to glass and the mechanical hardness of the film are excellent. Temperatures up to 400°C. have no effect on the reflection or adhesion, and most chemicals, even in strong concentration, do not attack the metal surface. The mirrors

can be manufactured in any thickness and are suitable for semitransparent mirrors. The price is high. Chromium mirrors can be produced similarly. Nickel mirrors are used for electrical purposes. E.D.M.

Glass-block manufacture. R. E. WALKER. *Pittsburgh People*, **2** [10] 16–17, 30 (1941).—A chart and 6 photographs show the processes of the manufacture of hollow glass block at the Pittsburgh Corning Corp.'s plant, Port Allegany, Pa.

Glass compositions for particular uses: selective transparency. B. M. PEARSON. *Ind. Chemist*, **18** [206] 79–80 (1942).—Glasses transparent to ultraviolet light and opaque to ultraviolet, infrared, or X rays are described. Transmission of the ultraviolet light is decreased by the presence of iron in the glass, by weathering, and by exposure to light. Good commercial ultraviolet ray-transmitting glasses transmit 40 to 80% of the short wavelength ultraviolet rays. Glasses with 40% lead oxide are almost as effective as the lead plates formerly used for protection against X rays, and the ease of observation is not impaired. Glass wool has many advantages as a heat- and sound-insulating medium, e.g., a wide temperature range and resistance to rot, etc. It has a low specific gravity and is unaffected by vibration, alternations of temperature, and acids. It may be used for air and gas filtration. A glassworks chemist's duties in works control and supervision are considered. E.D.M.

Glass as an engineering material. J. T. LITTLETON. Presented at meeting of American Ceramic Society, Cincinnati, April, 1942; abstracted in *Amer. Glass Rev.*, **61** [31] 9, 17, 19 (1942). A. P.

Glass waste in the rectangular cutting of lenses (calotte segment). F. STAEBLE. *Z. Instrumentenk.*, **61** [1] 26–29 (1941).—An exact formula is derived for calculating the amount of waste when a rectangular lens is cut from the complete round lens. The useful part of plane-convex lenses with a ratio of $d : R$ up to 0.4 (d = thickness in the middle and R = radius of the convex surface) is about 0.84 (waste 16%), and that of thicker lenses is about 0.77 (waste 23%). M.Ha.

Hardness and scratch resistance of plastics. DAVID STARKIE. *Jour. Soc. Glass Tech.*, **25** [115] 130–44T (1942).—A constructive effort was made to obtain dependable hardness and scratch-resistance tests for plastics and glass. The Brinell hardness test proved to be inaccurate; the ball impression was poorly defined, and the material recovery hindered exact readings. The pyramidal point was not sensitive enough to indicate small changes in hardness. The scratch test, performed by dragging a pyramidal point across a plane surface, gave variable results; the grooves were irregular and were not adequate for comparative readings. The multiple-point scraper gave general scratch-resistance comparisons of materials. A stream of silicon carbide particles impinging on a specimen from a definite height showed promise as a testing technique, and a special apparatus was constructed. The abraded spot was viewed by a photoelectric eye which was connected to a sensitive galvanometer. The falling silicon carbide test was used for classifying resins, glass, and surface coatings. The values are given in the following table:

Material	Scratch resistance
Polystyrene	12.1
Perspex transparent resin sheet	17.6
Cellulose acetate	20.6
Celluloid film base	21.8
Unplasticized Perspex sheet	30.0
Glass microscope slide	111.3
Common sheet glass	115.5
Polished plate glass	131.3
Pyrex brand (chemical) glass	183.2

The test is sufficiently sensitive to indicate the completeness of polymerization of certain thermoplastic materials. R.H.B.

Homogeneity of optical glass. W. FRASER AND MURRAY SCOTT. Presented at meeting of Glass Division, American Ceramic Society, Sept., 1939; abstracted in *Glass Ind.*, **20** [10] 362 (1939). A.P.

Ionic exchange in glass and the theory of the glass electrode. A. I. NIKURASHIN. *Byull. Khim. Obshchestva im. Mendeleeva*, **1940,** No. 9, pp. 10–11; *Khim. Referat. Zhur.*, **4** [3] 9 (1941). M.Ho.

Manufacture of optical glass. H. W. LEE. *Nature*, **150** [3798] 214–15 (1942).—L. describes the types and properties of optical glass manufactured by Messrs. Chance-Parsons. Thirty years ago, approximately a dozen types of glass were listed, refractive indices being given for four lines of the spectrum from C to G'. There are now nearly 100 types, and the data cover nine lines fairly evenly spaced over the visual spectrum from helium, b, to mercury, h. It is hoped that an extension of the data to include the infrared and ultraviolet will be a possibility before long. G.A.K.

Method for grinding the internal wall of small-bore capillaries. ELDER P. DE TURK AND ARTHUR E. LOCKENVITZ. *Rev. Sci. Instruments*, **13** [7] 295–96 (1942).—A method for grinding the internal wall of small-bore glass capillaries is described and illustrated. It consists of working a small brass wire of suitable diameter through the capillary, utilizing a grinding compound (silicon carbide grain No. 180 is recommended) and water, while the wire and capillary tube are automatically turned by means of an electric motor. H.E.S.

Modern methods of plate-glass manufacture: raw materials, machinery, and processing. B. M. PEARSON. *Ind. Chemist*, **18** [204] 10–14 (1942).—There are two important rival processes; in the older, the glass is cast on a table and rolled flat with a heavy iron roller. The glass must be rolled rapidly and placed in the annealing oven to avoid cracking, and highly skilled labor is required. The subsequent grinding and polishing operations reduce the finished plate to $^1/_2$ its original thickness, obviously a very costly process. The newer process is the continuous process developed by the Ford Motor Co. and introduced on a commercial scale in the U. S. in 1923. The glass is melted in a tank and flows between water-cooled rollers which press it to the desired thickness. The long annealing oven (400 ft.) introduced severe technical problems. As bubbles become elongated in the drawing process, easy planing of the glass is desired; the addition of barium helps by improving the fluidity. The new Bicheroux process is considered by some to be more economical than the continuous process. In this process, a thinner sheet of glass with a correspondingly larger surface is rolled out; while still hot, it is cut into smaller parts and annealed. In a further development of this process, the entire contents of the pot are poured out between two iron rollers and then rolled out. The same amount of molten glass yields twice the surface of rough plate glass, compared with the old table casting process, without increasing the work required for grinding and polishing. If the continuous melting system can be coupled with the Bicheroux process, a saving of about 50% of the total production costs could be achieved. Very careful selection and mixing of the raw materials is essential. The manufacturer has a wider choice of raw materials than the manufacturer of bottle glass, as the finished product is relatively expensive. Very careful balance of the batch is important, as the viscosity and setting rates of the glass are important. Cords, stones, drops, bubbles, and other optical defects are discussed in detail. The abrasive used during the grinding process is expensive, 10 lb. of sand being used in grinding 1 sq. ft. of glass surface, and any saving in abrasive is important. Automatic classifying devices are now employed on the grinding table, the waste sand being automatically regraded and returned to the grinding tables. The power supply is important (one plant in Illinois generates 14,000 h.p.). In the last 10 to 15 years, a serious competitor of the plate-glass industry has appeared, thick drawn window glass produced by the Fourcault or Libbey-Owens process, polished and sold as plate glass. It is in no sense an inferior material, and its production costs are somewhat lower than those for plate glass, primarily because less grinding and polishing are required. It is not feasible,

however, to draw window glass in widths greater than 5 ft. 6 in. In orthodox plate-glass manufacture, the thinner the sheet, the more expensive it is, but there is no practical limit to the thickness of sheet which may be drawn by the window-glass process. E.D.M.

Production of special glasses: problems of color and thermal expansion. B. M. PEARSON. *Ind. Chemist*, **18**, 60–63 (1942).—The coloring agents are divided into two groups: (1) those occurring in glass in true solution, and (2) those held in colloidal suspension. Cobalt produces a blue color and is one of the most powerful coloring agents known, 1 part in 20,000 giving a distinct blue color. The color is produced either under oxidizing or reducing conditions and cannot be burned out in working. Lead and potash glasses give a more brilliant blue than soda glasses. Barium gives a blue-green color with cobalt, and purple and violet shades are obtained by the addition of manganese. Copper in oxidizing batches gives a blue or green color and, in the colloidal state, produces copper ruby. Gold and selenium also produce rubies. Sulfur or graphite and manganese are used for amber glass, while iron or chromium is used for green glasses. Black glass contains about 10% iron oxide and 5% manganese oxide. Colored glass bottles are opaque to ultraviolet light and help delay the decomposition of foodstuffs, medicinals, etc., contained in them. The use of colored glass for decorative and architectural purposes has developed on a large scale. For this purpose, opaque glasses are also produced, cryolite (mainly synthetic) and fluorspar being the chief opacifiers. Some crystallization is induced in opal glass, and the question of brittleness arises, glasses with small uniform crystals being less brittle. The development of low-expansion (Pyrex brand) glass is considered. The use of glass for heat-transfer purposes is discussed, particularly in relation to its thermal conductivity. Copper has a thermal conductivity 300 times that of Pyrex brand glass, but it condenses only 2.5 times as much as the latter at rates of flow customary in plant practice. Chemical pipelines were one of the first applications of Pyrex brand glass. Tubes up to 18 ft. long and 3 in. in diameter are made. The limitation of length is represented by the requirements of safe shipment rather than by manufacturing limitations. Pressed perforated plates for reaction towers or column stills are now commonplace. Other uses of glass are based primarily on transparency along with chemical stability and resistance to temperature change. E.D.M.

Performance of glass tank furnaces. C. H. BOSANQUET. *Jour. Soc. Glass Tech.*, **26** [114] 108–12T (1942).—Papers by W. M. Hampton ("Proposed . . .," *Ceram. Abs.*, **21** [8] 168 (1942)) and W. A. Moorshead ("Principles . . .," *ibid.*, [9] 187) are discussed. R.H.B.

Quantitative spectrochemical analysis of boric oxide in glass. KENZO HARAI. *Jour. Chem. Soc. Japan*, **62**, 463–66 (1941); *Chem. Abs.*, **35**, 7667 (1941).—In borax glass the influence of PbO on the intensity ratio of the spectral lines was studied. The intensity ratio I_B/I_{Si} is constant when the ratio PbO/SiO_2 is smaller than 40% but decreases for the values greater than 40%. The mixture consisting of H_3BO_3 and SiO_2 is fused with Na_2CO_3, and the product is extracted with water. For the solution thus obtained the relation between log (B_2O_3/SiO_2) and log (I_B/I_{Si}) is found to be linear. See *Ceram. Abs.*, **21** [7] 141 (1942).

Significance of surface marks on fractured glass. J. B. MURGATROYD. *Jour. Soc. Glass Tech.*, **26** [115] 155–71T (1942).—Certain well-defined markings which regularly appear on new surfaces exposed when fracture occurs were studied; F. W. Preston designated them as "rib marks" and "hackle marks." A rib (1) represents a rest point in the forward movement of a fracture and (2) indicates a sharp change in direction of the fracture. The rib marks depend upon stress conditions which cause fracture; thus, a fracture advancing through a portion of a glass in tension which is adjacent to a portion in compression moves more slowly as it approaches the compression zone. Change of direction of fracture is attributed to variations in the applied stress. Experiments on the production of very slowly moving fractures indicated that the forces which cause fracture arrest are molecular and are not due primarily to the readjustment of the applied force. Rib marks indicate that the fracture moved relatively slowly (less than 1 cm. per sec.). Thermal-gradient and mechanical-loading experiments were made to study the production of rib-mark fractures. Hackle marks may be considered to be caused by a large shearing force causing simultaneous failure of the glass at several internal points; they usually result from explosive rupture due to large forces. Two interesting observations were made: (1) When hackle occurs on a fracture of a known direction of movement, it is found that the hackle commences inside the glass section, never at a surface. (2) Hackle marks have been observed only on fractures of such orientation that they lie at some angle other than 90° to the glass surface. The best examples of hackle structure are found in fractures which present an angle of about 45° to the surface of the glass containing them. R.H.B.

Specification of a method for determining the thermal endurance of glass in the form of rods. *Jour. Soc. Glass Tech.*, **26** [115] 60–63P (1942).—This method, drawn up by the Glass, Manufacture and Properties Committee, is given in full. Details of the testing of 50 rods (3 cm. long and 0.5 cm. in diameter) are included; a construction drawing of the special furnace is also provided. R.H.B.

Structure and constitution of glass. ERIC PRESTON. *Jour. Soc. Glass Tech.*, **26** [114] 82–107T (1942).—P. stresses the view that glasses at room temperatures are supercooled concentrated solutions. On the basis of the experimental work of Warren, the silicon-oxygen tetrahedron is thought to be the unit of structure of silicate glasses. X-ray research is responsible for much of the enlightenment in regard to the molecular structure of glasses, but still more research must be done on simple solutions to complete the picture of the silicate systems. Silicate compositions lying between the limits of two silicate compounds are thought to consist of chains of tetrahedra. A schematic diagram of the structure changes taking place in silicate glasses may be represented as follows:

$$Na_2O \longrightarrow \underset{\text{Free } Na_2O \text{ present in liquid}}{2Na_2O \cdot SiO_2} \longrightarrow \underset{\text{Chain structures progressing to rings}}{Na_2O \cdot SiO_2} \longrightarrow$$

$$\longrightarrow \underset{\text{Ring and sheet structures progressing to three-dimensioned units}}{Na_2O \cdot 2SiO_2} \longrightarrow \underset{\text{An infinite three-dimensional network}}{SiO_2}$$

In the silicon-oxygen unit, four oxygen atoms are attached to a silicon atom. The manner of bonding of metal atoms in silicate structures is still uncertain; further research must be performed before an adequate statement can be made. R.H.B.

Structure of sodium borate glasses as affected by temperature. A. E. BADGER, H. C. JOHNSON, AND J. O. KRAEHENBUEHL. *Jour. Amer. Ceram. Soc.*, **25** [14] 395–401 (Oct., 1942).—7 references, 7 figures.

Telescoptics. ALBERT G. INGALLS. *Sci. Amer.*, **167**, 142 (1942).—Work on the 200-in. telescope is to be suspended for the duration. The mounting is virtually complete, but about a year of work on the mirror remains. The mirror is to be finished to $^1/_{20}$ wave length. W.D.F.

Window design saves critical materials. S. KOFFSKY. *Eng. News-Record*, **129** [11] 353 (1942).—K. describes how considerable economy in critical building materials such as steel and putty was effected in window construction by eliminating alternative vertical members and using a double-width glass light, $28^3/_4$ x 20 in., in place of the 14- x 20-in. size. While a 2% increase in glass area was necessary, a saving of 17% in steel and 29% in putty was made. G.A.K.

Windows past and present. ANON. *Diamant*, **63** [10] 72 (1941).—The time of the introduction of glass windows is not known. The Chinese used fine materials coated with a bright lacquer or thin plates of horn or ground oyster shells. The Romans made windows of thinly ground agate, marble, or horn, isinglass, or mica. Glass windows for churches are mentioned first by the

historian Gregorius of Tours, in the 6th century. The glass windows in the Lateran Church in Rome were installed at the end of the 8th century by Pope Leo III. Glass windows appeared first in Germany in the 10th century and in France in the early 12th century. In England glass windows were used in residences as early as 1180, but in general windows were made of thin horn or metal wire screens. At first, window glasses were thick and were not very transparent. The first show window was built in Paris in 1711, and in the 19th century the use of large show windows developed. In 1880, New York had 4000 show windows, Berlin 3000, Paris 2000, London 1500, and Vienna 1000. M.Ha.

SEPARATE PUBLICATIONS

Electrical Insulation. Fiberglas Canada, Ltd., Oshawa, Ont. 20 pp. Reviewed in *Eng. Jour.*, **24** [12] 628 (1941).—The method of production of Fiberglas is described. It is used for electrical insulation as insulating tape, cordage, braided sleeving, and varnished or impregnated materials with a Fiberglas base. Illustrations, curves, and specification tables are included. G.A.K.

Glass and Its Adaptability to Modern Needs. Pittsburgh Plate Glass Co., Pittsburgh, Pa. 30 pp.—This brochure has been prepared at the suggestion of the Division of Substitute Materials of the Office of Production Management as a possible means of aiding manufacturers in finding substitutes for strategic materials which are no longer available for use in their products. Products of the Pittsburgh Plate Glass Co. are described, and availability information, properties, and suggested uses are given.

PATENTS

Ampoule and method of making. F. H. Wheaton, Jr. (T. C. Wheaton Co.). U. S. 2,297,335, Sept. 29, 1942 (April 21, 1939).

Apparatus for feeding glass to rolling machines. Joseph Gaskell (Pilkington Bros., Ltd.). U. S. 2,296,711, Sept. 22, 1942 (July 14, 1939).

Apparatus to produce bent glass. William Owen (Pittsburgh Plate Glass Co.). U. S. 2,297,315, Sept. 29, 1942 (March 28, 1941).

Apparatus for use in glass tempering. Alberto Quentin (vested in the Alien Property Custodian). U. S. 2,297,246, Sept. 29, 1942 (July 28, 1939).—A device for supporting glass sheets during a tempering operation.

Apparatus for use in tempering glass sheets. D. J. Sullivan and Gerald White (Libbey-Owens-Ford Glass Co.). U. S. 2,296,691, Sept. 22, 1942 (Nov. 17, 1939).

Frosting glass articles. Marvin Pipkin (General Electric Co.). U. S. 2,297,981, Oct. 6, 1942 (April 7, 1939).

Glass-cutting machine. R. H. Houck, J. F. Greene, and Oswald Behrend (Kimble Glass Co.). U. S. 2,297,149, Sept. 29, 1942 (July 2, 1938).

Glass-envelope seal. H. R. Seelen (Radio Corp. of America). U. S. 2,296,579, Sept. 22, 1942 (Nov. 30, 1940).

Glassforming apparatus. E. H. Wellech (Corning Glass Works). U. S. 2,296,321, Sept. 22, 1942 (July 16, 1938).

Glass-supporting apparatus. T. G. Weihs (American Window Glass Co.). U. S. 2,297,181, Sept. 29, 1942 (Aug. 15, 1940).—Apparatus for supporting a glass sheet in substantially vertical position during the tempering.

Glassware-forming machine. G. B. Langer (Lynch Corp.). U. S. 2,296,935, Sept. 29, 1942 (Feb. 21, 1940).

Glassworking apparatus. R. A. Hinkley and E. H. Wellech (Corning Glass Works). U. S. 2,296,347, Sept. 22, 1942 (Feb. 28, 1938).

Laminated product. Adolf Kämpfer (vested in the Alien Property Custodian). U. S. 2,297,417, Sept. 29, 1942 (Oct. 21, 1939).

Making glass-to-metal seals. D. W. Power (Radio Corp. of America). U. S. 2,296,307, Sept. 22, 1942 (April 30, 1940; Feb. 28, 1941).

Making hollow blocks. O. W. Wiley (Pittsburgh Corning Corp.). U. S. 2,297,337, Sept. 29, 1942 (June 1, 1940).

Marking on a body of glass. Marconi's Wireless Telegraph Co., Ltd., C. P. Fagan, and E. G. Herriott. Brit. 547,170, Aug. 26, 1942 (Feb. 14, 1941).

Means for producing fibers from suitable molten materials. D. C. Drill (American Rock Wool Corp.). U. S. 2,295,639, Sept. 15, 1942 (Jan. 6, 1936; April 22, 1939).

Optical glass. Edwin Berger and Karl Rehm (vested in the Alien Property Custodian). U. S. 2,297,453, Sept. 29, 1942 (Nov. 25, 1940).—An optical glass having an index of refraction, n_D, and an Abbe constant, ν, whereby $n_D > 1.86 - 0.004\nu$ and containing substantial quantities of boron oxide, bivalent oxides, and lanthanum oxide, the content of boron oxide amounting at the most to 25%, the content of barium oxide amounting to at least 25%, the content of barium oxide and of other oxides of earth alkalis as well as of zinc oxide and lead oxide amounting in total to at least 45%, and the content of lanthanum oxide amounting to 20% at the most.

Recovery of wastes from glass grinding and polishing operations. R. R. McGregor (N. S. Garbisch). U. S. 2,297,628, Sept. 29, 1942 (Dec. 4, 1939); divided out of U. S. 2,182,384 (*Ceram. Abs.*, **19** [2] 45 (1940)).—(3) A process of removing finely ground glass from the mixture of pulverulent glass and silica resulting from the surfacing of glass plates with sand as an abrasive, which process comprises digesting the mixture with hot water under pressure in an autoclave to form sodium silicate solution from the glass, then removing the solution from the residue of silica and insoluble glass constituents. (4) A process of forming sodium silicate comprising digesting, with a dilute water solution of alkali, the mixture of finely divided sand and glass resulting from the surfacing of plate glass with a water slurry of sand as an abrasive for a time sufficient to effect selective reaction of the alkali with the glass content of the mixture to form alkali silicate while leaving most of the sand unattacked.

Sheet glass forming apparatus. G. W. Batchell. U. S. 2,297,737, Oct. 6, 1942 (June 17, 1939).

Structural Clay Products

Clay units save metal for radiant heating. Anon. *Brick & Clay Record*, **101** [1] 14–16 (1942).—Clay ducts used for carrying warm air are laid in a floor, thus utilizing the entire floor area for radiating heat. B.C.R.

Cost of reopening a brick plant. Anon. *Brick & Clay Record*, **100** [6] 23 (1942).—After an eleven-year idle period, during which minor repairs were made, the expenses of placing a plant in only satisfactory operating condition amounted to $30,000. Considerably more would have been necessary to put the equipment in first-class condition. B.C.R.

Inventory of structural clay products research programs. Harry C. Plummer and Frederick Heath, Jr. *Bull. Amer. Ceram. Soc.*, **21** [9] 194–96 (1942); see *ibid.*, **18** [12] 466–67 (1939).

Rebuilding barns with clay tile. J. M. Anderson. *Brick & Clay Record*, **100** [6] 24–25 (1942).—Hollow tile may be used advantageously in replacing the rotted frame walls below the mow floors in remodeling work. Illustrated. B.C.R.

Urge wider use of brick and clay products. Anon. *Eng. News-Record*, **129** [12] 390 (1942).—Producers of brick and other clay products are urged by the War Production Board to gauge production to meet an anticipated increased demand for these materials to replace lumber in both temporary and permanent structures. It is be-

lieved that at least 2,000,000 board feet of lumber could be saved by increased utilization of brick and tile. G.A.K.

PATENTS

Design for vitrified traffic marker. D. R. SEVER AND D. J. RENKERT (Metropolitan Paving Brick Co.). U. S. 133,943, Sept. 29, 1942 (July 26, 1941).

Wall structure. J. E. MACDONALD (McFeely Brick Co.). U. S. 2,295,352, Sept. 8, 1942 (Oct. 4, 1941).

Refractories

Conference on refractories at the Institute of Metallurgy, Academy of Sciences, U.S.S.R. R. L. PEVZNER. *Izvest. Akad. Nauk S.S.S.R., Otdel. Tekh. Nauk*, **1940**, No. 7, pp. 99–108; *Khim. Referat. Zhur.*, **4** [2] 89 (1941). M.Ho.

Graphite crucibles in wartime. J. DESMOND. *Iron & Coal Trades Rev.*, **145** [3878] 353–54 (1942).—Graphite crucibles for melting metals are usually made from graphite imported from Madagascar and Ceylon. Because of importation difficulties, hints and handling methods are given for prolonging the life of graphite crucibles as much as possible. As these crucibles absorb as much as 10% of their own weight of moisture, they should be stored in a warm dry place at about 80° to 100°F., carefully preheated to 250° before use in a melting furnace, and then slowly heated up to the required temperature. They should rest preferably on plumbago or firebrick stands on a perfectly even surface. In melting, it is inadvisable to add cold metal to a molten charge; if all the metal cannot be charged at once, the remainder should be added before the initial charge is completely melted. Tilting furnaces should be charged in a vertical position, and the metal should be placed loosely in the crucible and not jammed, as otherwise the crucible will crack because of the greater expansion of the metal. In firing, the heat around the crucible should be as uniform as possible, and the correct ratio of fuel to air must be maintained so that there is a neutral or slightly reducing atmosphere at the flue outlet; an oxidizing condition extracts carbon from the crucible wall, leaving a porous structure liable to crack. M.Ha.

Handling refractories. ANON. *Steel*, **111** [3] 84–85 (July 20, 1942).—The modern methods of handling refractories with pallets, fork trucks, tractors, conveyers, etc., are discussed. The advantages include a decrease in handling costs and a saving of time by both the maker and the user, expansion of brick-house storage capacity, protection of shapes from damage, and consequent speeding of masonry operations. Illustrated. H.E.S.

Heat-treatment of refractory materials. NELSON W. TAYLOR AND SAMUEL ZERFOSS. *Heat Treating & Forging*, **28** [5] 244–48 (1942).—Thermal-expansion measurement, the petrographic microscope, X-ray diffraction apparatus, the differential thermocouple, and the electron microscope are useful research tools in studying refractory materials. Phase-equilibrium diagrams indicate important characteristics of mixtures of various components. Polymorphic changes in refractories produce volume changes which may be severe enough to shatter the brick or to cause gradual disintegration. Each of the different crystalline forms is stable throughout a definite temperature range. The change to another form with change of temperature may be rapid or very slow. These changes are reversible. Monotropic changes are similar, except that they are irreversible. Other reactions affecting firebrick are the filling of the pores by graphite when reducing atmospheres are present and the mottling of silica brick. Even at temperatures below a red heat, many minerals or mineral products are quite reactive. S.S.

Investigation of refractory material in Martin furnaces working at a greatly increased rate. R. L. PEVZNER. *Izvest. Akad. Nauk S.S.S.R., Otdel. Tekh. Nauk*, **1940**, No. 5, pp. 25–42; *Khim. Referat. Zhur.*, **4** [2] 89 (1941).—When a furnace is worked at a greatly increased rate, the first zone (cristobalite) of Dinas reaches up to 130 mm. with an average of 50 to 60 mm., whereas at normal conditions it is only 30 to 35 mm. At an ordinary working rate, the slag corrosion is such that the SiO_2 content in the first zone is higher than that in the second (tridymite); but at an increased rate more SiO_2 was found in the second than in the first zone. To insure a greater resistance of the Dinas under increased working rates, a good tridymitized Dinas with a specific gravity of not more than 2.37 should be used. M.Ho.

Low-temperature calcined grog. E. K. KELER. *Ogneupory*, **8** [4] 198–204 (1940); *Khim. Referat. Zhur.*, **4** [1] 110 (1941). M.Ho.

Manufacture of carbon blocks for blast-furnace hearths. G. R. RIGBY, H. BOOTH, AND A. T. GREEN. *Bull. Brit. Refrac. Research Assn.*, No. 59 (June, 1941); reprinted in *Trans. Brit. Ceram. Soc.*, **41** [5] 144–47 (1942).—Literature on the manufacture and use of carbon blocks in blast-furnace hearths is reviewed. The preparation of briquettes from foundry coke and gasworks pitch is described, and the feasibility of dry-press or tamping methods of manufacture is demonstrated. The properties of specimens prepared in the laboratory compared favorably with those of a German commercial product. R.A.H.

Manufacture of high-quality low-cost steel. J. P. MCKIMM. *Iron & Coal Trades Rev.*, **143** [3844] 404–405 (1941).—In the manufacture of steel, economy, i.e., tons per furnace-hr., is of prime importance; all factors of furnace design should conform to this constant predetermined factor. The Bosshardt furnace, with an interconnected gas producer at each port end, is given as an example for realizing good economy; a 150-ton furnace with a depth of 20 to 32 in. gave 15.3 to 17.2 net tons per hr. Materials for furnace bottoms are now made of magnesite from continental Europe and a high iron refractory which has a lower MgO and higher Fe_2O_3 content; open-hearth slag is added to the mixture in both cases. Analyses of typical bottoms are given in the following table:

Compound	Dead-burned magnesite	High-iron refractory	Slag
MgO	82	30	4
CaO	5.50	55	35
Fe_2O_3	4	11	20
Al_2O_3	1–2	1–2	Trace
SiO_2	7	3–4	11

In actual furnace operation, the care and maintenance of furnace bottoms are more important than initial installation. After tapping a heat, the bottom must be thoroughly drained and dried before another heat is charged. Any holes or other defects must be filled while making up the bottom and banks regardless of the time element. Charging and melting times must be adapted to the kind of steel to be made; tables of scrap weight required for making up the number of charging boxes are given. M.Ha.

Producing tamped mullite refractory. V. RYBNIKOV AND P. ALIMOVA. *Novosti Tekhniki*, **1940**, No. 11–12, p. 25; *Khim. Referat. Zhur.*, **4** [1] 110 (1941). M.Ho.

Substitute for magnesite brick for Martin furnaces. A. S. BEREZHNOĬ. *Rabochiĭ Met.*, **1940**, No. 8, pp. 9–10; *Khim. Referat. Zhur.*, **4** [2] 89 (1941).—B. describes the preparation of chrome-magnesite, chromite, forsterite, and dolomite brick used in place of magnesite brick. See "Production of special . . .," *Ceram. Abs.*, **18** [9] 245 (1939); "Utilization . . .," *ibid.*, **20** [8] 195 (1941). M.Ho.

Use of Missouri refractories in blast-furnace service. CHARLES A. FREEMAN. *Blast Furnace & Steel Plant*, **29** [11] 1119–22 (1941).—Tests of physical characteristics indicate that, for all three sections of the furnace, Missouri refractories compare favorably with or are superior to those from Pennsylvania and Kentucky. Missouri clays low in iron and capable of being fired hard enough to resist the abrasion of the top section are plentiful. These top-quality refractories resist impact and possess good spalling

resistance. Missouri clays also possess to a great degree the natural characteristics desirable for inwall quality: resistance to abrasion, slag action, and CO disintegration and imperviousness to possible penetration of gases and vapors. Missouri superduty hearth- and bosh-quality refractories are permanent in volume, showing a slight shrinkage to a slight increase in volume in a long reheat test at 3000°F. Hard-fired superduty brick have excellent load-bearing strength and are unaffected by CO at high concentrations for long periods of time at critical temperatures. Under test conditions, any CO disintegration usually develops within 50 hr., but hard-fired Missouri superduty brick have shown no apparent effect after 1000 hr. B.L.

SEPARATE PUBLICATIONS

Refractory Brick (Der Schamottestein). RUDOLF RASCH. Chemisches Laboratorium für Tonindustrie, Berlin. 230 pp. Price Rm. 12. Reviewed in *Tonind.-Ztg.*, **64** [58] 425–27; [59] 438–39 (1940). H.T.

Relation of Permeability and Specific Gravity of Insulating Refractories. P. G. HEROLD, LEONARD STEARNS, AND W. J. SMOTHERS. *Univ. Missouri, School Mines & Met., Tech. Ser. Bull.*, **14** [4] 51 pp. (March, 1942).—Insulating refractories and backing-up heat-insulation materials are classified purely on their refractory value. While this classification is of interest in determining the maximum service temperature at which the insulator will operate, it gives no indication of the insulation value. The apparent permeability was determined on a sample 4 in. in diameter and $2^1/_2$ in. thick by passing air through the sample at various pressures. When the apparent permeability was plotted against pressure, a straight line was obtained, except at comparatively high pressures when turbulent flow was obtained as evidenced by a decrease in apparent permeability. The complete curve approximated a parabola. A correlation was made between the absolute permeability and the bulk density which may be easily determined. It was found that, for the low service temperature group, an average sample had a low bulk density, a low absolute permeability, and a high pressure at which viscous flow changed to turbulent flow. This showed that the sample had a large number of pores to satisfy the low bulk density, the capillaries connecting the pores must be large to give a high "turbulent pressure" value, and the major portion of the pores must be closed to give a low permeability. The converse was noted for the higher service temperature groups. P.G.H.

PATENTS

Heat-resistant wall panel. W. H. MARCHANT. U. S. 2,296,392, Sept. 22, 1942 (Feb. 28, 1940).

Highly refractory mass. KARL DIETZ (vested in Alien Property Custodian). U. S. 2,295,637, Sept. 15, 1942 (Feb. 6, 1941).—A method of producing highly refractory hydraulic mortars, tamping material, materials for repairs and coating, and shaped bodies therefrom which comprises mixing cement powders obtainable by calcining and then cooling and finely grinding compounds of magnesia selected from the group consisting of magnesium oxide and magnesium silicates with alumina sol.

Process for extraction of alumina from clays and shales. J. G. STEIN & CO., LTD., AND J. F. HYSLOP. Brit. 547,265, Sept. 2, 1942 (April 29, 1941).

Refractory casting. T. E. FIELD (Corhart Refractories Co.). U. S. 2,297,546, Sept. 29, 1942 (July 19, 1941).—A heat-cast refractory consisting of zirconia, chromic oxide, alumina, and iron oxide, in which any silica present amounts to less than 4% by weight and the moles of iron oxide are less than the sum of the moles of the alumina plus chromic oxide.

Skewback. C. H. ALDRICH (American Metal Co., Ltd., and International Nickel Co. of Canada, Ltd.). U. S. 2,294,946, Sept. 8, 1942 (Oct. 6, 1939).

Suspended furnace wall. W. H. MARCHANT. U. S. 2,296,391, Sept. 22, 1942 (Feb. 28, 1940).

Treating magnesia. NORTON CO. Brit. 546,642, Aug. 6, 1942 (Oct. 27, 1939).

Terra Cotta

Mistakes in making floor tile and their prevention. ONNI DAHL. *Sprechsaal*, **73** [45] 401–403; [46] 411–13; [47] 419–22; [48] 432–34 (1940).—Most difficulties are due to carelessness rather than to poor materials or lack of knowledge. Defects may be divided into the following classes: (1) curved or angular cracks or crazing, (2) laminations and spalling, (3) bubbles and pimples, (4) porosity, (5) fused places, (6) deformations, (7) discoloration, and (8) injuries such as broken edges. Cracks are most common, and it is difficult to tell whether they are caused by faulty drying or firing. If they arise in drying, they may be detected before firing by wetting the tile with oil. Initial stresses causing dry cracking may be due to inadequate grinding of the raw material, too plastic a clay, or compression of the body material when it is too warm or unevenly moist. Dry cracking from exterior causes may be due to drafts of air, cold saggers, damp sand, or unfired spacers. Cracks arising during firing may be simply enlargements of drying cracks, or they may have their origin in firing and be due to insufficient drying, too rapid temperature changes, or exposure to cold air or moisture in the firing chamber. Cooling cracks are less frequent than drying or firing cracks and are always caused by too rapid a rate of cooling after vitrification. The permissible rate of cooling varies with the materials. Crazing, which occurs least frequently, may be due to wetting of the tile or sudden changes of temperature during firing or cooling. The separation of layers occurs often and is greatly feared. This may happen directly after pressing, some minutes later, or during drying or firing. It is better and cheaper in doubtful cases to destroy a few hundred freshly pressed pieces in examining them for laminations than to take from the kiln thousands of unsalable tile. The causes of laminations are similar to those of cracks, i.e., unsuitable materials used for pressing, poor operation of the press, or defective molds. Spalling of the upper layer may be due to variation in shrinkage or vitrification temperature of the body or to variations in moisture. Spalling of large pieces may be due to insufficient drying or to sudden heating. Bubbles do not occur often; they indicate the formation of gas from the burning of extraneous matter such as wood or coal. Bubbles may be avoided by slow heating so that the gas can escape while the tile is still porous. Thin bubbles of large diameter may be due to firing bituminous clays under reducing conditions or to insufficient drying and too rapid rise of temperature. Small pimples are due to foreign incombustible matter. Such foreign matter is especially dangerous because, if it lies deep enough, it cannot be detected. Pimples may be due to quartz, flint, grog, or lime. Small bubbles over the whole surface may be due to overfiring. Failure to keep the press plate clean gives the tile a porous surface. Local fusion on the surface of the tile is caused mainly by neglect in the preparation of the body. Iron causes the most trouble. Small white spots are due to particles of feldspar; spots of a great variety of colors and sizes are due to other impurities. Combustible impurities may accidentally come to the surface of the tile and leave holes when burned. If a tile is thicker at one edge than at the other, the press needs adjustment. If a tile is not rectangular, there are two causes: poor manipulation in filling the mold or variation in firing temperature from one corner of the mold to another. Deformation of tile not caused by overfiring may be due to drying or firing on uneven supports or to improper placing of the tile in the kiln. Surface discolorations are due to inadequate drying of the tile, vitrification, or firing under reducing conditions. It is advisable to maintain the finishing temperature for a sufficient time to obtain the complete vitrification needed for the density and color of the surface. Bituminous clays are especially

sensitive to the reducing flame. The type of flame and the rapidity of temperature rise and fall have a great effect on the color. Flue ashes or sand may form a coating on the tile if the saggers are not tight. Pyrites in the fuel may cause a white deposit. Tile may also be damaged by carelessness in placing them on the drying racks, putting them in the saggers, or loading them loosely into freight cars. See "Defective . . .," *Ceram. Abs.*, **19** [4] 93 (1940). W.H.H.

Pottery glazes for stove tile. ANON. *Keram. Rundschau*, **45** [30] 336–37 (1937).—To obtain a tile glaze which adheres well and is as colorless as possible, scratch resistant, and stable to chemicals, a body containing lime is necessary because its expansion coefficient is greatly lowered. Lead glazes and the use of zinc oxide and lime to adapt the expansion coefficient to the body and to increase scratch resistance and stability are discussed. Glazes without lead or tin oxide can be worked with calcium borate. Mat glazes are obtained by small additions of magnesite or titanium white, whether or not lead or boric acid is present. M.V.C.

PATENTS

Caps for chimney pots and ventilator terminals. E. HURDEN AND J. C. SNELLING. Brit. 546,742, Aug. 12, 1942 (Dec. 30, 1941); divided out of Brit. 546,714, Aug. 12, 1942 (Dec. 16, 1940).

Chimney pots and ventilator terminals. E. HURDEN AND J. C. SNELLING. Brit. 546,714, Aug. 12, 1942 (Dec. 16, 1940).

Whiteware

Beryllium in ceramics. LAKAFF. *Keram. Rundschau*, **49** [14] 142–43 (1941).—Be oxide in ordinary ceramic bodies favors mullite formation and therefore increases mechanical strength. As it acts as a flux and has a softening point 200°C. higher than that of feldspar, it can replace feldspar for very high temperature requirements. The addition of Be to electrical porcelain bodies increases not only the electrical resistance but also tensile and impact strengths and resistance to temperature changes. Comparison of a body composed of 10.83 Be oxide, 48.54 clay, 28.98 feldspar, and 11.65% quartz with a Be-free body shows an increase in temperature resistance of 145%, in electrical resistance of 17%, in impact resistance of 44%, and in tensile strength of 21.4%. An addition of Be is recommended for acidproof and refractory ceramic bodies. Of particular interest is the use of Be oxide in glazes; as a flux it dissolves a large amount of alumina, makes the glaze harder, and, in particular, makes the green high-temperature glazes of Cr more refractory. The simultaneous presence of Be and Cr oxide in batches and glazes produces fine emerald-green tones which are very resistant to the effects of furnace gases and which do not change into gray, black, or reddish tones as do glazes containing Cr oxide alone. The use of Co oxide with Cr and Be oxides gives fine blue and turquoise tones, but in this case the Be material must be entirely free of Fe. The most important Be mineral is beryl, a silicate ($Be_3Al_2Si_6O_{18}$), which contains about 10 to 12% Be oxide. A less frequent Be mineral, phenacite, contains about 45% Be oxide. Common beryl is opaque, whitish, or yellowish and occurs in crystals up to 6 in. in height and 18 tons in weight, mainly in pegmatitic gangues of granite; it is mined mainly in Norway, France, and the U. S., and recently also in Canada. Beryl is very refractory and resistant to chemical attack. The oxide is similar to the oxides of the alkaline-earth group, has a melting point of 2400°C., and can be used up to 2000°C. As its thermal expansion coefficient is very low, it resists abrupt temperature changes; it has a still higher electrical resistance than sintered corundum. M.HA.

Chemical engineering and ceramics. C. S. GARLAND. Presented at meeting of Institution of Chemical Engineers; *Ind. Chemist*, **18** [207] 116–17 (1942).—The development of insulators to withstand the increasingly high voltages used in the electrical industry is described. The demand of the gas industry for jets resistant to sudden changes in temperature led to the industrial development of steatite, a Bavarian mineral. Eventually, a synthetic magnesium silicate was produced which not only had all the properties of natural steatite but, in some respects, was superior to it. It proved to have the lowest loss factor known. It thus became of vital importance in short-wave transmission. It is possible to deposit on it a highly coherent layer of silver which can then be electroplated with copper, etc. It has a hardness between that of quartz and topaz, is tough and elastic, has a high compressive strength, and has the capacity to take a high degree of polish. If the firing is stopped at 900°C., the resulting product, while so hard that it can readily be handled or worked, is soft enough to be treated as a nonferrous metal. Gears and bearings can be made wholly of this material and require only water lubrication. E.D.M.

Effect of sulfur and reducing gases on a semivitreous dinnerware glaze and decalcomania decoration. I. J. W. MACHATTIE AND A. E. R. WESTMAN. *Jour. Amer. Ceram. Soc.*, **25** [14] 416–20 (Oct., 1942).—11 references.

Improved ceramics. ANON. *Product Eng.*, **13** [6] 349 (1942).—Ceramic materials with improved mechanical and electrical properties are listed in a table (see page 238).

Influence of flint particle size on permanent moisture and thermal expansion in porous earthenware bodies. W. E. PALMER. *Jour. Amer. Ceram. Soc.*, **25** [14] 413–16 (Oct., 1942).—6 references, 4 figures.

Porcelain insulator design—American development to meet changing industrial needs. ANON. *Electrician*, **128** [3328] 222–23 (1942).—The production of Prestite by the Westinghouse Electric & Mfg. Co. is briefly described. The possibility of the substitution of this material for aluminum in water coolers and its value in saving third-rail power loss are discussed. See "Prestite . . .," *Ceram. Abs.*, **21** [1] 18 (1942). H.K.R.

Reduction and elimination of lead and boron in pottery glazes. BERDEL. *Keram. Rundschau*, **47** [49] 515–16, 518 (1939).—B. states that fritted glazes without any boric acid material were made several hundred years before the boric acid-containing English earthenware glazes appeared In discussing the questions of color (yellowish tones), fusibility, and a tendency to form fine cracks, he concludes that the elimination of boric acid from lead-containing and even lead-poor glazes is quite possible if a satisfactory medium between the difficult fusion of boron-free glazes and the tendency to form fine cracks can be found; it is necessary to find by trial the greatest amount of lime, magnesia, and zinc oxide that can be used together with the greatest possible amount of potassium and sodium. Mixtures of low fusibility (eutectic) should be used, not of the type

$$\left.\begin{matrix}K_2O\\CaO\\PbO\end{matrix}\right\}\ \text{but of}\ \left\{\begin{matrix}K_2O\\Na_2O\\CaO\\MgO\\ZnO\\PbO\end{matrix}\right.;$$

as an example of a B-free glaze for

Seger cone 02*a* to 1*a*, B. recommends

$$\left.\begin{matrix}0.20\ K_2O\\0.20\ Na_2O\\0.20\ CaO\\0.05\ MgO\\0.05\ ZnO\\0.30\ PbO\end{matrix}\right\}0.25\ Al_2O_3\cdot 2.5\ SiO_2.$$

The batch is as follows: frit: 112 Scandinavian feldspar, 21 calcined soda, 20 calcite, 4 magnesite, 4 zinc oxide, 46 red lead, and 72 quartz sand; mill addition: 258 frit, 13 kaolin, and 26 white lead. Such frits are much more viscous than B-containing batches. If lead oxide is to be eliminated entirely from glazes, the alkali content must be

[NOTE: This table accompanies the abstract entitled "Improved ceramics," p. 237.]

Materials	Dense steatites ($MgO \cdot SiO_2$)	Rutile bodies (TiO_2)	Cordierite bodies ($2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$)	Natural lava	Porcelain	
					Dry process	Wet process
Mechanical properties						
Hardness (Mohs' scale)	7.5	8	7	6		
Tensile strength (lb./in.²)	7500–10,000	7500	1500– 3500	2000– 2500	1000– 2000	5000– 8000
Compressive strength (lb./in.²)	65,000–85,000	80,000	30,000–40,000	20,000–30,000	30,000–50,000	45,000–90,000
Modulus of rupture (lb./in.²)	18,000–22,000	20,000	4000– 8000	8000– 9000	6000– 8000	10,000–18,000
Impact resistance (ft.-lb./in.²) (Charpy)	1.8–2.1	2.4	0.9	1.3–1.4		
Electrical properties						
Dielectric strength (volts/mil)	210–240	100		80–100	40–100	250
Dielectric constant: 60~	6.3–6.5					
1000 kc.	5.8–6.2	85	4.1–5.0	5.3–5.6	6.0–7.0	6.0–7.0
10,000 kc.	5.7–6.0	85	4.0–5.0	5.3–5.5	(41–1000 kc.)	(1–1000 kc.)
Power factor (%): 60~	0.14–0.30				1.70–2.50	1.70–2.50
1000 kc.	0.02–0.20	0.08	0.40	0.30–1.00	0.80–1.00	0.80–1.00
10,000 kc.	0.01–0.18	0.06	0.30	0.25–0.90	0.60–1.00	0.60–1.00
Loss factor (%): 60~	0.88–1.95				10.20–17.50	10.20–17.50
1000 kc.	0.13–1.24		1.64–2.00	1.68–5.30	4.80–7.00	4.80–7.00
10,000 kc.	0.06–1.08		1.20–1.50	1.37–4.77	3.60–7.00	3.60–7.00
Volume resistivity (ohms/cc.)						
at 25°C. (77°F.)	$>10^{14}$	$>10^{12}$	$>10^{14}$	$>10^{12}$	$>10^{15}$ (at 75°C.)	$>10^{13}$ (at 75°C.)
at 100°C. (212°F.)	2.1×10^{12}–$>10^{14}$	9.8×10^{11}	6.1×10^{12}–4.0×10^{13}	3.2×10^{11}		
at 500°C. (932°F.)	3.2×10^{8}–3.5×10^{10}	1.7×10^{6}	4.8×10^{6}–2.0×10^{7}	1.7×10–2.6×10^{8}		
at 900°C. (1652°F.)	$<10^{11}$–2.5×10^{7}	$<10^{4}$	7.0×10^{4}–2.2×10^{5}	2.0×10^{4}–1.8×10^{6}		
Thermal properties						
Softening point (°F.)	2550–2630	3000	2570–2600	2700–3000		
Heat resistance (°F.)	1830	1830	2280	2000–2190		
Coefficient of expansion (per °C. at 20°–100°C.)	7.8–10.4×10^{-6}	8.6–8.7×10^{-6}	2.5–2.8×10^{-6}	3.4–10.5×10^{-6}	3.0–6.0×10^{-6}	3.0–6.0×10^{-6}
Thermal conductivity (cal./sec. cm. °C.)	0.006		0.003	0.003–0.005		
General properties						
Specific gravity	2.6–2.7	4.0	2.1	2.3–2.8	2.3–2.5	2.3–2.5
Weight (lb./in.³)	0.094–0.098	0.144	0.076	0.085–0.102		
Chemical resistance	Resistant to all common acids and alkalis except hydrofluoric acid					
Water absorption (%)	1.00–0.00	0.05–0.00	8.0–1.0	2.5–1.0	1.0–0.5	0.00

Rutile bodies are mixed with a small amount of plastic clay for workability and are used for only relatively simple shapes. Cordierite materials have an extremely low thermal expansion and withstand thermal shock well.

M. HA.

increased to avoid an increase in the fusion temperature. An example of Pb- and B-free glazes for Seger cone O2*a* to l*a* is given as follows:

$$\left.\begin{matrix}0.15\ K_2O\\0.30\ Na_2O\\0.05\ MgO\\0.15\ ZnO\\0.35\ CaO\end{matrix}\right\}0.22\ Al_2O_3\cdot 2.0\ SiO_2.$$

Batch: frit: 84 Scandinavian feldspar, 32 calcined soda, 4 magnesite, 12 zinc oxide, 35 calcite, and 58 quartz sand; mill addition: 188 frit and 18 kaolin. Success is not always sure because of white opacification, fine cracks, and devitrification. A small addition of lead oxide (about 0.1) to the above batch will prevent these defects; the frit should then be made up of 84 Scandinavian feldspar, 27 calcined soda, 4 magnesite, 12 zinc oxide, 30 calcite, and 58 quartz sand; mill addition: 182 frit, 18 kaolin, and 26 white lead. M.HA.

Running of glaze slips. ANON. *Keram. Rundschau*, **46** [50] 581 (1938).—The running of glaze slips where the slip is too thin and does not have the correct specific gravity, although the usual amount of water has been added, is caused by the dissolving out of alkalis (electrolytes) either because of too-fine grinding or because the slip has been left standing too long. To counteract this condition, a few drops of acetic or hydrochloric acid are stirred in until litmus paper shows only a slight reaction. Constant stirring is necessary to remove the gas bubbles generated. If the glaze still runs, a fixative such as Epsom salts, which has the advantage of being inexpensive, is added. M.V.C.

Simple method for testing lead oxide in industry. ANON. *Keram. Rundschau*, **46** [51] 593 (1938).—The purity of the raw materials, e.g., lead, minium, and litharge, is a decisive factor in the production of light-colored lead oxide glazes. Where a chemical analysis cannot be made, satisfactory control can be achieved by a fusion test and comparison of the sample with a known material as follows: 60 gm. of the lead oxide to be tested and 40 gm. finely ground sand are weighed, mixed thoroughly, and rubbed together on a palette; 60 gm. of a known and tested lead oxide is treated in the same way. Equal quantities of the samples are placed on a plate which has been biscuit fired, either as a glaze or, better, in drops, and fired. The color and degree of flow of the samples are compared. Any dark specks present in the litharge will show up here. A slight difference in the yellow coloring is unimportant, but where the result is doubtful, further tests can be made with a simple copper oxide glaze (60 litharge or minium, 35 sand of Hohenbocka, and 5% copper oxide); small amounts of clay impurities easily produce a color change. To control the degree of fineness of lead oxide, which is important in the production of raw glazes, the procedure is as follows: a tall 10-cc. measuring glass is filled with the powder to be tested and is shaken by tapping the base until the powder no longer settles. The glass and its contents are weighed, and the weight of the glass is subtracted. The difference shows the weight in gm. of 10 cc. The scales must be accurate to within 0.1 gm. Comparative weights are tabulated, and finely divided and therefore unsuitable minium is shown to weigh less than coarser minium. M.V.C.

PATENTS

Ceramic process. J. R. THOMPSON (Hall China Co.). U. S. 2,296,961, Sept. 29, 1942 (Oct. 2, 1940).—The uninterrupted slip-casting method of forming an inverted bowl having integral exterior handles and an exterior integral hollow supporting base which consists in forming the bowl and handles in the matrix of a closed stationary mold having an open central mold cavity forming an upper extension of the matrix, then rotating the mold, and slip-casting the bowl base by centrifugal force in the mold cavity.

Electrical insulating material and method of producing. NORTON CO. Brit. 546,641, Aug. 6, 1942 (Oct. 27, 1939).

High-tension insulator. J. R. NELIS. U. S. 2,297,713, Oct. 6, 1942 (June 12, 1941).—An insulator body of dielectric material in the form of a rod having integral tapered knobs at the respective opposite ends.

Insulator knob. L. A. STOHL. U. S. 2,295,872, Sept. 15, 1942 (Dec. 21, 1939).

Making electrical insulating material. NORTON CO. Brit. 546,643, Aug. 6, 1942 (Oct. 27, 1939).

Manufacture of appendaged pottery ware. W. J. MILLER. U. S. 2,294,926, Sept. 8, 1942 (March 15, 1937).

Method and apparatus for manufacturing pottery ware. W. J. MILLER. U. S. 2,298,223, Oct. 6, 1942 (June 8, 1940).

Porous ceramic articles and method of making. G. S. DIAMOND (Electro Refractories & Alloys Corp.). U. S. 2,297,539, Sept. 29, 1942 (May 31, 1938).—A porous permeable ceramic article, including granules of a sintered and crushed aluminum silicate material comprising hard dense granules and screened to pass through an approximately 14-mesh screen and to be retained on an approximately 30-mesh screen, and a bond constituting not more than $^1/_5$ of the weight of the finished article and including approximately equal parts of a siliceous material and litharge, the bond having a fusing point below the sintering temperature of the aluminum silicate material and forming vitrified envelopes of the bonding material about the particles of the sintered material and a bond between such particles.

Spark-plug insulator. GENERAL MOTORS CORP. Brit. 546,769 and 546,770, Aug. 12, 1942 (May 9, 1940).

Spark plug for internal-combustion engines. LODGE PLUGS, LTD., B. HOPPS, AND C. J. SMITHELLS. Brit. 547,119, Aug. 26, 1942 (July 15, 1941).

Equipment and Apparatus

Attenuated superconductors for measuring infrared radiation. D. H. ANDREWS, W. F. BRUCKSCH, JR., W. T. ZIEGLER, AND E. R. BLANCHARD. *Rev. Sci. Instruments*, **13** [7] 281–92 (1942).—An apparatus for measuring infrared radiation has been constructed of fine tantalum wire; it operates at a temperature of 3.22° to 3.23°K. in the transition zone between superconduction and normal conduction. The tantalum coil is mounted on a thermostated plate with the temperature electrically controlled and operates in a special self-regulating shunt circuit by which its own temperature is automatically maintained constant. The ratio of developed electrical potential to radiation flux received is $150\ \mu$ v (erg cm.$^{-2}$ sec.$^{-1}$)$^{-1}$. The minimum detectable flux is about 10^{-3} erg sec.$^{-1}$. Absolute measurements of intensity of radiation from sources at temperatures between 24° and 55° are consistent with the Stefan-Boltzmann law, showing that instrument corrections for reflectivity, window absorption, and changes with wave length are very small. H.E.S.

Bailey open-joint checker. ANON. *Steel*, **111** [2] 6–11 (July 13, 1942).—The open-joint checker manufactured by the William M. Bailey Co., Pittsburgh, Pa., is illustrated and explained. The checkers, which are used as a lining for blast-furnace stoves, are composed of an inlet checker, a top checker, and a straight checker. It is claimed that they will positively equalize the flow of gases throughout the entire checker chamber due to complete cross circulation. Side passages from each flue have a greater area than the flue itself, thereby forcing gases to flow across the entire checker chamber as well as through the vertical flues; this causes maximum turbulence and therefore maximum efficiency. Other advantages claimed are maximum brick weight in the hot zones of the stove and stable construction due to column design and the method of locking the checkers. H.E.S.

Chemical engineering aspects of centrifugal-fan design. CARL V. HERRMAN. *Trans. Amer. Inst. Chem. Engrs.*, **38** [2] 365–76 (1942).—The factors in centrifugal-fan de-

sign which are of particular importance when handling corrosive or erosive gases are discussed. The ways in which these factors can modify the more standard details of the regular ventilating-fan designs are reviewed. 7 references. E.D.M.

Clay-water relationships and the internal mechanism of drying. H. H. MACEY. *Trans. Brit. Ceram. Soc.*, **41** [4] 73–121 (1942); rewritten from *Bull. Brit. Refrac. Research Assn.*, No. 36 (March, 1935); No. 39 (April, 1936); No. 44 (Oct., 1937); No. 45 (May, 1938); and No. 49 (March, 1939).—M. describes the "inner mechanism" of drying, whereby the moisture-content gradients, which are the ultimate cause of cracking, are set up. It has been shown how and why these gradients are set up and how they may be calculated in the case of linear flow. With this understanding of the inner mechanism of drying it remains necessary, if possible, to extend the calculations into two or three dimensions and to discover the maximum gradients a clay can withstand without cracking and why and how these gradients may be reduced and the drying strains may be alleviated, so that losses from these sources may be diminished or rates of drying increased. R.A.H.

Costs of process equipment and accessories. HARDING BLISS. *Trans. Amer. Inst. Chem. Engrs.*, **37**, 763–804 (1941).—The degree of accuracy required for preliminary cost estimates usually does not warrant the time spent in correspondence with manufacturers, and much economy of time would result if rough cost approximations were available. B. presents information on the original costs of various items of process equipment and the effects thereon of important variables such as construction material, size, and type. Certain information other than first costs is helpful, e.g., installation and maintenance costs, depreciation rates, and performance data, so that power requirements and size specifications can be calculated more exactly; these are included where possible. The equipment considered comprises pipe and tubing, fittings, gate valves, heat exchangers, liquid pumps, gas pumps, thickeners, filters, crystallizers, driers, absorption towers and packing, and tanks, storage vessels, and linings. E.D.M.

Development and status of machinery for fine ceramics: VI and VII. W. SCHLEGEL. *Keram. Rundschau*, **49** [2] 15–18; [21] 207–12 (1941).—S. describes modern machinery for grinding and mixing fine ceramic batches in both batch and continuous processes. American machinery has often been the prototype for development, especially in dry-mixing processes. Diagrams of the arrangement of machines and apparatus are shown from the preparation of the raw material to the final mass ready for forming and firing. For Parts **I–V** see *Ceram. Abs.*, **21** [4] 86 (1942). M.Ha.

Dust-collecting and gas-cleaning installations. HENRY L. MUNGOMERY LARCOMBE. *Mining Mag.*, **66**, 143–50, 206–15, 256–60 (1942).—L. reviews the factors influencing the application, design, and character of apparatus of this type. W.D.F.

Electrically heated screens. ANON. *Brick & Clay Record*, **101** [1] 18–19 (1942).—Clogging of screens resulting from the adherence of slightly moist clay can be prevented by heating the screens electrically. A considerable saving and increased production result. B.C.R.

Electrostatic generator for nuclear research at M.I.T. L. C. VAN ATTA, D. L. NORTHRUP, R. J. VAN DE GRAAFF, AND C. M. VAN ATTA. *Rev. Sci. Instruments*, **12** [11] 534–45 (1941).—The electrostatic generator which was previously located at Round Hill was transferred to the Massachusetts Institute of Technology grounds in Cambridge in 1937. A complete picture of the generator construction and the high-voltage accelerating tube is presented by means of drawings and descriptions. The design of operational equipment is discussed clearly. The acceleration of positive ions, electron beams, and X-ray bombardment of indium, beryllium, and deuterium are explained with respect to the experimental work performed thus far. R.H.B.

Flame descaling. E. W. DECK. *Steel*, **110** [22] 81, 84 (1942).—Flame descaling with oxyacetylene is a method for removing the iron oxide scale which forms on steel surfaces during exposure to oxidizing atmospheres at relatively high temperatures. The method is valuable for alloy steels which are difficult to descale. It can replace much grinding, thereby improving working conditions and operating efficiency. E.D.M.

Gamma-ray radiography of welded high-pressure power-plant piping. R. W. EMERSON. Presented at meeting of American Society for Testing Materials, June, 1942; abstracted in *Combustion*, **14** [1] 37–40 (1942). H.E.S.

Insulating salt-bath pots. ANON. *Heat Treating & Forging*, **28** [5] 243 (1942).—A new electric salt-bath furnace designed for low temperatures uses brick insulation only at the corners where the electrodes are placed and on the floor. The brick are held in place with angle iron and can be easily renewed. S.S.

Keeping belt-drive machines running. J. R. HOPKINS. *Concrete, Cement Mill Ed.*, **50**, 189–90 (1942).—Belt drives can be operated 24 hr. a day if the belt is maintained. The following precautions are given: (1) Keep the belts dressed. (2) Make all leather belts endless by using an endless lap. (3) Be sure that the belt thickness is correct for the pulley diameters. (4) Be sure the belt is the right size for the load. (5) Be sure the pulleys are large enough to keep the belt speeds up. With V-belt drives (*a*) use larger sheaves and more belts than the minimum recommended; (*b*) buy matched sets of belts; (*c*) do not pry the belts over the side of the grooves but shift the motor instead; (*d*) keep the sheaves aligned; (*e*) keep them tight; (*f*) replace worn sheaves; (*g*) keep them clean; and (*h*) replace a whole set at once and save the old ones for spares. W.D.F.

Laboratory pressure flowmeter. L. J. BRADY AND B. B. CORSON. *Ind. Eng. Chem., Anal. Ed.*, **14** [8] 656–57 (1942).—The authors have developed a metal flowmeter capable of measuring gas rates as low as 500 cc. per hr. at normal temperature and pressure. The instrument described was designed for a maximum working pressure of 140 kgm. per sq. cm. (2000 lb. per sq. in.), but this type of flowmeter can be designed for much higher pressures. In construction it is similar to the usual glass flowmeter, except that the orifice is a longitudinal scratch on the surface of a cylinder which fits snugly in a steel barrel, and the height of mercury is measured electrically. Details of construction and operation are given. Illustrated. F.G.H.

Magnetic separations in petrography. GORDON C. MATHISRUD. *Amer. Mineralogist*, **27**, 629–37 (1942).—Clean magnetic separations of mixtures of rock minerals are uncommon for several reasons, including two important reasons that have not received much attention: (1) As most magnetic separators are designed, they attract large grains more strongly than small grains; apparently, even a difference in size of 0.03 mm. is great enough to cause trouble. (2) The different members of several isomorphous series are differently attracted by strong magnets; the series from Mg to Fe compounds shows a wide range in attractability. Magnets can probably be designed to reduce or eliminate the effect of grain size, but it cannot be expected that zoned crystals which have a range of compositions will be cleanly separated from other minerals. W.D.F.

Maintaining proper lubrication. ANON. *Combustion*, **14** [1] 29–32 (1942).—The selection and application of lubricants for power-plant operation and maintenance is discussed. H.E.S.

Maintenance and servicing of electrical instruments. JAMES SPENCER. *Instruments*, **15** [2] 48, 50–57 (1942). B.C.R.

Making production equipment last longer. ANON. *Factory Management & Maintenance*, **100** [8] 151–52 (1942).—Lubrication, replacement, and repair as maintenance measures are dealt with. N.R.S.

Materials to be ground, lining brick, Alsing cylinders. ANON. *Keram. Rundschau*, **46** [32] 361 (1938).—Practical suggestions are given for lengthening the life of linings and cylinders and increasing efficiency. M.V.C.

New method for the determination of viscosity at high shearing stresses and definite rates of shear: I. F.

WACHHOLTZ AND W. K. ASBECK. *Kolloid-Z.*, **93,** 280–97 (1940); *Chem. Abs.*, **35,** 5767 (1941).—The theories of flow of both true and anomalous liquids and methods of determining their viscosities are reviewed. Three viscometers were constructed for the investigation of the viscosity, at various rates of shear, of pigment-oil suspensions. A rotating-disk instrument was unsuitable because of temperature rises during its operation. A close-clearance falling-ball viscometer showed evidence of turbulence at high rates of shear. To meet 10 stated requirements of an ideal viscometer, a band viscometer was designed. It is, in effect, a cylinder-type instrument of infinite radius. It is concluded that the band viscometer is suitable for measurements on suspensions at high rates of shear. **II.** *Kolloid-Z.*, **94,** 66–81 (1941); *Chem. Abs.*, **35,** 6173 (1941).—The band viscometer was used in studies of viscosity behavior of pigment suspensions. At 20° the relation between rate of shear and shearing stress for 45 vol. % TiO_2 in mineral oil is best described by the Bingham equation, whereas for 10 vol. % TiO_2 in stand oil the Ostwald equation serves at least as well. To facilitate comparisons, apparent viscosity at infinite rate of shear, $\eta^*\infty$, was calculated for each suspension. The course of the log $\eta^*\infty$ vs. vol. % pigment is not affected by the $\eta^*\infty$ of the oil but is influenced by pigment particle shape. Log $\eta^*\infty$ for suspensions of a given concentration is a straight-line function of log $\eta^*\infty$ for the base oils used. Chemical interaction between pigment and oil changes the curve without destroying the straight-line relation. See "Tape . . .," *Ceram. Abs.*, **21** [10] 219 (1942).

Particle-size studies. Effect of viscosity of medium on rate of grinding in pebble mills. H. E. SCHWEYER. *Ind. Eng. Chem.*, **34** [9] 1060–65 (1942).—Particle-size distributions in the subsieve ranges were used to study the development of surface and the decrease in top size in pebble-mill operations using fluid media of different viscosities. It was found that, under the conditions used, the development of surface takes place in two stages. In the initial period, the rate of surface development is essentially constant and is a function of the viscosity of the medium. In the second period, the rate decreases and is practically independent of the viscosity of the medium. The rate of decrease of top size was rapid at the start but decreased with time of grinding; it is a function of the viscosity of the fluid medium used. Illustrated. F.G.H.

Pipette-type capillary viscometer for substances which are solid or highly viscous at room temperature. J. F. WEILER. *Ind. Eng. Chem., Anal. Ed.*, **14** [8] 634 (1942).—W. describes construction and operation of a viscometer which was developed for routine determinations of the kinematic viscosities of the heavier products resulting from the destructive hydrogenation of coal. Illustrated. F.G.H.

Power-plant piping and piping problems. H. F. BEHRENS. *Combustion*, **14** [2] 30–39 (1942).—B. discusses the piping which would be employed in a steam power station designed for a medium pressure of approximately 900 lb. and 900°F. total steam temperature. The discussion covers the main steam lines, small high-temperature piping and fittings, flanges, bends, hangers and connections for blowdown, feedwater heaters, evaporators, circulating water lines, ash handling and fire protection, and welding. H.E.S.

Removing insoluble deposits from turbine rotor. ANON. *Combustion*, **14** [1] 28 (1942).—The removal of soluble deposits on turbine blades can usually be accomplished (1) by washing with wet steam at reduced load and speed or (2) during overhaul by subjecting the nozzles and buckets to a strong jet of water and compressed air. Insoluble deposits, such as silica, can be removed very effectively by means of a blast of fly ash. If properly applied, it will not injure the turbine blades. Illustrated. H.E.S.

Scanning electron microscope. VLADIMIR K. ZWORYKIN. *Sci. Amer.*, **167,** 111–13 (1942).—The purpose of the scanning electron microscope is to provide as high a magnification of opaque objects as the electron microscope does for transparent objects. An electron gun shoots a beam of electrons through one reducing lens, an aperture in an inclined fluorescent screen, and a second reducing lens and is focused on a spot 25 μ in diameter on the object. This produces secondary electrons which come back and form an image on the fluorescent screen. An electron multiplier amplifies this, and a magnetic device makes the electron focus scan the object. The final picture is obtained by means of a facsimile receiver which produces a picture in 8 min. It is designed to resolve a spot only 100 a.u. in diameter. W.D.F.

Scoop trucks replace wheelbarrows. ANON. *Brick & Clay Record*, **100** [6] 36, 38 (1942).—In the Chester, Pa., plant of the Harbison-Walker Refractories Co., electric scoop trucks handling 1800 lb. have replaced wheelbarrows in transporting raw materials from the boxcars to the crusher. Lift trucks can carry and tier 275 brick. Many advantages are claimed. B.C.R.

Selection and installation of flowmeters. RAYMOND E. SPRENKLE. *Instruments*, **15** [3] 75–82 (1942). B.C.R.

Technique and applications of industrial microradiography. G. L. CLARK AND S. T. GROSS. *Ind. Eng. Chem., Anal. Ed.*, **14** [8] 676–83 (1942).—Because of widespread interest in the possibilities of the technique of microradiography as an industrial testing and research method, details of the best equipment, procedures, and applications developed at present are given. As it is impossible to magnify X-ray images in the same sense that optical images are magnified by suitable lenses, it is necessary to register the X-ray image on a photographic plate and then enlarge the photographic image. By use of the Lipmann emulsion with extremely fine grain size for the silver halide, a magnification of up to 300 may be made without loss of detail from graininess. Successful radiography also depends upon the choice of X-ray wave lengths which will give a suitable differentiation between constituents in a specimen, such as aluminum and copper in an alloy used in the construction of aircraft. A new technique employing two or more characteristic radiations to bring out details of polycomponent metal systems is presented and illustrated with a variety of alloys such as copper-beryllium, aluminum-magnesium, aluminum-copper, bronze, leaded iron, rolled beryllium, silicon steel, graphitic steel, season-cracked brass, and lead-antimony type metal. Instead of employing very soft X rays generated with special equipment at a few thousand volts and applicable to a very limited number of materials, and without vacuum cameras, very successful results were obtained with characteristic Kα rays of molybdenum, copper, iron, cobalt, chromium, etc., as produced in ordinary diffraction apparatus. It is demonstrated that microradiography supplements the microscope in metallurgical and other industrial applications, with the following advantages: (1) it gives a three-dimensional view of the specimen; (2) it does not depend upon differential action of etchants but only on the variations in absorbing power of constituents, including internal voids and cracks; (3) it requires no special polishing of the specimen; and (4) it is directly and incontrovertibly interpreted. A few striking biological applications, especially in wood technology, are illustrated. F.G.H.

Testing and improving the drying behavior of clays. H. G. SCHURECHT AND J. F. MCMAHON. *Jour. Amer. Ceram. Soc.*, **25** [14] 422–24 (Oct., 1942).—4 references, 2 figures.

PATENTS

Abrasive-throwing machine. G. A. BOESGER (W. W. Sly Mfg. Co.). U. S. 2,295,926, Sept. 15, 1942 (Aug. 3, 1938).

Apparatus for the manufacture of pottery ware. W. J. MILLER. U. S. 2,296,364, Sept. 22, 1942 (June 11, 1938).

Increasing the density of a mass of granular material. D. W. ROSS. U. S. 2,295,294, Sept. 8, 1942 (Nov. 5, 1938; July 22, 1939).—The method of increasing the density of a mass of size-graded granular materials including in part grains that manifest the piezoelectrical phenomenon and in part grains that do not manifest such phenomenon which consists in subjecting the mass to differ-

ently directed electrical forces and producing in the mass piezoelectrical vibration-producing stresses.

Method and apparatus for glazing ceramic ware. J. A. BOWER (Taylor, Smith & Taylor Co.). U. S. 2,295,928, Sept. 15, 1942 (April 29, 1938).

Method and apparatus for manufacturing pottery ware. W. J. MILLER. U. S. 22,187, Sept. 29, 1942 (April 24, 1942); reissue of original, U. S. 2,243,880, June 3, 1941 (March 1, 1929; March 20, 1936).

Particle-size grading and product. D. W. ROSS. U. S. 2,297,169, Sept. 29, 1942 (Nov. 12, 1941).—The method of forming particle-size gradations that comprises grading fines according to the formula $y = x^3$, in which y = the part of the whole that will pass through any given screen having segregating action and x = the size of the mesh of that screen expressed as a function of the ratio of the mesh size to the largest particle size of the fines, and compounding the so-graded fines with a body of coarser particles in such proportion that the coarser particles stand substantially free from contact with each other in the body of the fines.

Pug mill. R. G. BELLEZZA AND E. M. SKIPPER (Locke Insulator Corp.). U. S. 2,297,646, Sept. 29, 1942 (March 9, 1940).

Kilns, Furnaces, Fuels, and Combustion

Burning midwestern coals on traveling-type grates. JOHN CRUISE. *Combustion*, **14** [3] 42–43 (1942).—The design of the furnace and the arrangement for the admission of air best adapted to the burning of coals with mildly caking characteristics in stokers of the traveling-grate type are discussed. The influence of arches on the rate of ignition penetration and the maintenance of proper grate temperature are also discussed. H.E.S.

Combustion calculations by graphical methods—wood and bagasse. A. L. NICOLAI. *Combustion*, **14** [2] 40–44 (1942).—Charts for conveniently arriving at the combustion values of wood and bagasse are given. The commercial use and other applications are pointed out. See *Ceram. Abs.*, **21** [9] 195 (1942). H.E.S.

Comparison of round and rectangular kilns. T. W. GARVE. *Brick & Clay Record*, **100** [4] 29–30 (1942).—In comparing round and rectangular kilns, G. tabulates the advantages and disadvantages of each, indicating a relative superiority of the rectangular kiln even though the round kiln shows lower construction cost, longer life, and better heat distribution. **Comments.** *Ibid.*, p. 31. B.C.R.

Fundamental aspects of heat transmission by radiation from flames and furnace linings. E. C. W. SMITH, A. L. ROBERTS, AND D. T. A. TOWNEND. *Jour. Soc. Glass Tech.*, **26** [114] 113–29T (1942).—The fundamental principles of heat transmission in furnaces are discussed with the purpose of suggesting possibilities for increased thermal efficiency; particular stress is placed on heat transfer by radiation from combustible products and heated furnace walls. The total radiation emitted by a body is proportional to the fourth power of its absolute temperature. The wave length of maximum emission of radiation is given by the expression $\lambda_{max.} = \alpha T$, where α = a constant = 0.29, T = °K., and $\lambda_{max.}$ = cm. In view of the fourth-power law, the walls and crown of the furnace should be raised to as high a temperature as possible. Calorific value of fuel, good mixing of gases, and turbulent flow over the walls are important factors for thermal efficiency. Hydrocarbon-containing fuels possess continuous emission from the carbon particles in the flame. With aerated nonluminous flames, almost all radiation is emitted by carbon dioxide and water molecules; these materials have a selective emission. With opaque materials, emissivity is essentially a surface phenomenon. The rate of convectional transfer is a function of the temperature difference between the gas and the wall, the density and velocity of the gas, the contact area, and the coefficients of diffusion and turbulence. Infrared emission and adsorption play an important part in the melting of glass. Infrared radiations are useful for the quick drying of paints, varnish, etc. Proper insulation materials may be used to advantage in reducing heat losses. R.H.B.

Guard against spontaneous combustion when storing coal. W. D. LANGTRY. *Brick & Clay Record*, **100** [5] 21–22 (1942).—In piling coal, segregation should be avoided as this permits the air to enter through the outer portions containing the coarser lumps. Air may be successfully eliminated by rolling each three-foot layer of the coal with a tractor or a bulldozer as the pile is built up. Coal showing no excessive heating in 90 days can usually be stored longer without difficulty. Clay plants can use abandoned clay pits for storing their coal under water; otherwise this method is not very applicable. Methods of ventilating coal piles have not been successful, as, usually, insufficient air is passed through the pile for proper ventilation. B.C.R.

Latitude in coal selection through plant modernization. T. MAYNZ. *Combustion*, **14** [2] 45–46 (1942).—The experiences of one plant in burning Fairmont District coal are given. With the original boilers and stokers it was impossible to attain the expected steam output. These were later rebuilt, replacing the refractory setting with water cooling and firing with underfeed stokers of both the water-cooled and the air-cooled types. With these changes, satisfactory performance has been attained. Two other units in the plant which burn this coal in pulverized form regularly carry the base load at full output without difficulty. H.E.S.

Pointers on the storage of coal. J. F. BARKLEY. *Combustion*, **14** [1] 33–35 (1942).—The loss of the heating value of coal in storage has commonly been overestimated. The slacking of coal in storage is greater with low-grade coals such as lignite, subbituminous coals, etc. Spontaneous combustion can be prevented or lessened by (1) storing coal under water, (2) compressing the pile in layers as with a road roller, (3) storing large-size coal, (4) preventing segregation of sizes in the pile, (5) storing in small piles and keeping the storage height as low as possible, (6) storing the coal away from any external sources of heat, (7) avoiding any draft of air through the coal, and (8) using older portions of the storage first, avoiding accumulations of old coal in corners. H.E.S.

Tunnel kiln in the grinding-wheel industry. L. BENDA. *Keram. Rundschau*, **49** [14] 139–42 (1941).—Although grinding wheels are usually fired in circular furnaces, the advantages of the continuous tunnel kiln for this work, due to its flexibility, are discussed. Grinding wheels will stand very rapid cooling when red-hot without injury, but they must be very carefully cooled from both sides in the temperature range between 650° and 500°C., as all tensions and stresses which might later lead to cracking must be avoided. The tunnel kiln permits temperature control at exactly such zones. Temperature control, heating period, waste-gas temperature (preferably 150°C. in the main shaft), and general features of furnace design are discussed. M.HA.

Utilization of low-grade fuels in gas producers. M. W. THRING. *Jour. Soc. Glass Tech.*, **26** [115] 145–54T (1942).—Recommendations pertaining to the use of low-grade fuels are given. The basic theory of gasification is presented with a view to developing better methods of firing. The problems of producer operation discussed include (1) caking and swelling, (2) size, size distribution, and friability, (3) ash content and ash characteristics, and (4) volatility content and reactivity. The reduction of voids in the part of the bed first reached by the air is important for the attainment of producer gas and low temperatures. Coke additions to the fuel promote a more uniform gasification rate. The use of a feed cylinder is suggested to reduce the carry-over of dust when gasifying dusty or friable fuels. Fuels with a wide size ratio are best gasified in producers designed to segregate the large particles away from the walls. Clinkering of fuels with low ash-fusion tempera-

ture may be reduced by the addition of sand; mechanical stirring of the fuel bed aids in breaking up the clinkers and bridges. T. believes that these principles may be used to advantage in furnace operations. R.H.B.

What's happening inside your kiln? II, Gas flow. L. R. WHITAKER. *Brick & Clay Record*, **100** [3] 28–30 (1942).—In downdraft kilns, the gases tend to rise to the crown and descend through the ware to the stack unless a tight setting or a high draft is used. In the latter case, the gases are apt to move more horizontally. Elimination of the bag wall facilitates watersmoking of the ware in the lower part of the kiln. In tunnel kilns, the brick on the lower part of the kiln car may not be watersmoked sufficiently before passing into the firing zone unless proper firing schedules are used. **III, Watersmoking.** *Ibid.*, [4] 43–44. With the use of fast watersmoking schedules, insufficient time may be allowed for all the ware to dry thoroughly; wet brick may thus be subjected to high temperatures, resulting in the production of punky or discolored brick. **IV.** *Ibid.*, [6] 16–17.—W. discusses the relative advantages and disadvantages of the use of high and low drafts during the watersmoking periods. The type of ware set determines to some extent the draft used. **V.** *Ibid.*, **101** [1] 17–18.—The formation of soot on the ware during the watersmoking period prevents it from drying properly due to the high insulating properties of the soot. Rapid heating of the ware at 300°F. or higher may result in slabbing. Soot formation is less likely to occur in tunnel kilns. Under proper conditions, most nearly met in tunnel kilns, watersmoking may be completed in 8 hr. or less, while in downdraft kilns, it often requires 48 hr. B.C.R.

SEPARATE PUBLICATION

Typical Analyses of Coals of the United States. A. C. FIELDNER, W. E. RICE, AND H. E. MORAN. *U. S. Bur. Mines Bull.*, No. 446, 45 pp. Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 10¢.—A summary of the composition of commercial coal resources of the U. S. is presented in tabular form. The degree of metamorphism from lignite toward anthracite is given for many of the coals. R.A.H.

PATENT

Sagger. A. R. BOOK. U. S. 2,297,286, Sept. 29, 1942 (Jan. 30, 1940).—A composite sagger comprising a one-piece bottom tile of refractory composition, a plurality of refractory corner post members secured to the bottom tile, a plurality of separate side-wall tile members of refractory material resting edgewise on the bottom tile and having a loose interfitting engagement with the corner posts, the corner-post members and the side-wall members forming a complete enclosure around the edge of the bottom tile.

Geology

Calculation of mineralogical composition of feldspar by chemical analysis. E. W. KOENIG. *Jour. Amer. Ceram. Soc.*, **25** [14] 420–22 (Oct., 1942).—4 references.

Chemistry of soils. L. T. LOWE. *Chem. & Ind.*, **61** [21] 230–32 (1942).—Pedology is the term given to the study of soils, and this branch of science finds itself interrelated with chemistry, physics, geology, and microbiology. Much progress is being made with regard to soil formation and soil mechanics through the concerted efforts of many investigators. The latest developments in soil science are reviewed. Rock minerals are largely complex aluminosilicates. The most important change involved in weathering is hydrolysis; a typical example is the formation of kaolinite according to the following equations:

$$\underset{\text{(potash feldspar)}}{K_2O\cdot Al_2O_3\cdot 6SiO_2} + 2H_2O = \underset{\text{(converted to } K_2CO_3 \text{ by } CO_2 \text{ in the soil water)}}{H_2O\cdot Al_2O_3\cdot 6SiO_2} + 2KOH$$

$$\underset{\text{(kaolinite)}}{H_2O\cdot Al_2O_3\cdot 6SiO_2} + H_2O = Al_2O_3\cdot 2SiO_2\cdot 2H_2O + 4SiO_2.$$

In ordinary weathering, it is noted that Na_2O is lost more quickly than K_2O, and the ratio of K/Na can be used as an index of the stage of weathering. The chief soil groups of the world are as follows: (1) Soils of cold wet regions—podsol. (2) Soils of arid regions—alkali soils. The alkaline formation is believed to be represented by the following reactions: (*a*) Ca clay + 2NaCl = Na clay + $CaCl_2$, (*b*) $CaCl_2$ is washed down, and (*c*) Na clay + Ca $(HCO_3)_2$ = Ca clay + $2NaHCO_3$ or Na clay + H_2O = H clay + NaOH (this will then form Na_2CO_3 with the CO_2 of the soil water). (3) Soils of temperate regions with moderate rainfall—black earths (chernozems). Brown forest soils. (4) Soils of the humid tropics—laterites and lateritic soils. Weathering in these regions has been much more complete owing to the higher temperatures. In the presence of water, clay shows the properties of an electronegative colloid; ignition destroys the colloidal properties. The clay particle appears to consist of a crystal lattice made up of anions, which are mainly silica, alumina, and iron oxides, surrounded by a swarm of cations, which may comprise calcium, hydrogen, sodium, potassium, and other monovalent and divalent metals, and may be represented as follows:

	$Ca^{\cdot\cdot}$		$Ca^{\cdot\cdot}$		$H^{\cdot}$	
	Al_2O_3		SiO_2		Al_2O_3	
		Fe_2O_3		Fe_2O_3		
$Na^{\cdot}$	SiO_2		Al_2O_3		SiO_2	$H^{\cdot}$
	Al_2O_3		SiO_2		M_2O_3	
	$K^{\cdot}$		$Ca^{\cdot\cdot}$		$H^{\cdot}$	

In the presence of water, a double electric sheath is formed around the particle, the anionic sheath occupying the interior position. The stability of the suspension in water depends on the potential difference between the anionic and cationic sheaths which is given by the formula potential difference $= \frac{ed}{Dr^2}$, where e = electric charge on the particle, d = mean radial distance between the anionic and cationic sheaths, r = radius of the particle, and D = the dielectric constant. The flocculation of clay occurs when the potential is reduced below a certain critical value; it is accomplished by (*a*) causing some of the cations to rejoin the particle and thus neutralize part of its negative charge (adding an electrolyte has this effect by reducing the dissociation of the cations); (*b*) reducing the mean radial distance between the anionic and cationic sheaths (this effect follows when highly hydrated cations such as sodium are replaced by less hydrated cations such as calcium which can approach the particle more closely); (*c*) increasing the dielectric constant. Flocculation is complicated by two other actions: (1) base exchange, whereby cations form the flocculating agent and replace those associated with the clay particle,

$$\underset{\leftarrow\text{Clay}\rightarrow}{Al_2O_3\cdot n SiO_2}\begin{cases}Ca^{\cdot\cdot}\\ Na^{\cdot}\\ K^{\cdot}\\ H^{\cdot}\end{cases}\underset{\leftarrow\text{Solution}\rightarrow}{+\ Na^{\cdot} + Cl'} = \underset{\leftarrow\text{Clay}\rightarrow}{Al_2O_3\cdot n SiO_2Na^{\cdot}}$$

$$\underset{\leftarrow\text{Clay}\rightarrow}{\qquad\qquad} + \underset{\leftarrow\text{Solution}\rightarrow}{[Ca^{\cdot\cdot} + K^{\cdot} + H^{\cdot}] + Cl'}$$

(2) precipitation of insoluble salts on the surface of the particle, whereby the negative charge is reduced. This occurs when hydroxides of calcium, magnesium, barium, and strontium are used. Soil acidity is determined by direct titration, the use of the quinhydrone electrode, the use of the glass electrode, or electrometrically; the acidity of soils has a direct bearing on plant life. The humus content of soils as the result of organic decomposition is responsible for acid soil conditions. R.H.B.

Chile's manganese resources. FERNANDO BENITEZ G. *Eng. Mining Jour.*, **142** [10] 38–42 (1941).—The northern zone of manganese mineralization contains one or more parallel beds of ore, mainly psilomelane and braunite. Mines in this zone have been idle since about 1900. The more southerly zone has less regular beds associated with limestones. The principal mineral is pyrolusite. The

reserves of 35% ore amount to about 300,000 tons; this would have to be sorted. Reserves of possible ore of 30% Mn amount to 1,200,000 tons. The cost, in U. S. dollars, per ton of the ore at the port varies from $6.10 to $8.60. The concentratability of these ores is being tested. W.D.F.

Composition of soil colloidal clay. D. I. SIDERI AND A. N. LIAMINA. *Soil Sci.*, **54** [2] 83–99 (1942).—Clays of the Quaternary depositions of the Russian plain were studied by means of X-ray, chemical, and thermal methods. It was found that the chief component of these clays is a mineral of the formula $3SiO_2 \cdot Al_2O_3 \cdot 0.5(KH)O \cdot H_2O$ + bound H_2O, designated as "paramontmorillonite." This mineral was found to be intermediate in its properties between kaolinite, sericite, and a montmorillonite-like mineral which is described. N.R.S.

Composition, specific gravity, and refractive indices of rhodochrosite; rhodochrosite from Butte, Montana. RUSSELL G. WAYLAND. *Amer. Mineralogist*, **27**, 614–28 (1942).—New data on rhodochrosite are presented, including hitherto unpublished analyses. Seventy-nine analyses are calculated to $MnCO_3$, $FeCO_3$, $MgCO_3$, and $CaCO_3$ and are plotted in three ternary diagrams. The frequency of appearance of Ca, Fe, and Mg in significant quantities as isomorphous constituents of the 79 rhodochrosite specimens is found to be in the ratio 21:17:12. Complete isomorphous miscibility with calcite and siderite is demonstrated. The series to magnesite is incomplete. The refractive indices and specific gravities of rhodochrosite are shown to vary directly with the composition and to be calculable from it. The composition of a specimen, however, cannot be deduced from the specific gravity and optical properties alone. The $n\bar{O}$ of pure $MnCO_3$ is shown to be 1.816 and the specific gravity 3.70. The theoretical specific gravity calculated from the molecular weight and volume of a unit cell is considerably larger. The average molecular composition of rhodochrosite from Butte, Montana, is $MnCO_3$ 90.7, $MgCO_3$ 7.4, and $CaCO_3$ 1.9%. Butte rhodochrosite is lower in iron and higher in magnesium than most rhodochrosites. W.D.F.

Deposits of high alumina crude and their comparative evaluation. P. A. BORISOV. *Sbornik Leningrad. Geol. Uprav.*, **1940**, No. 5, pp. 14–34; *Khim. Referat. Zhur.*, **4** [3] 25 (1941).—B. lists the physicochemical and technical properties of sillimanite minerals and their deposits in the U.S.S.R. and abroad. The deposits of the Kola peninsula are discussed in detail. M.Ho.

Discussion of "Unusual asymmetrically banded fissure vein." EARL INGERSON. *Amer. Mineralogist*, **27**, 649–51 (1942).—Each of the eight steps as outlined by Shaub (*Ceram. Abs.*, **21** [9] 199 (1942)) is open to question. The evidence from the pictures, coupled with experimental data, indicates that deposition and replacement by a homogeneous dilute solution can probably explain all the features; such a vein could not have formed from "concentrated immiscible mineral solutions." W.D.F.

Elasticity of glass at high temperatures and the vitreous basaltic substratum. FRANCIS BIRCH AND DENNISON BANCROFT. *Amer. Jour. Sci.*, **240** [7] 457–90 (1942).—The elasticity and internal friction of several specimens of glass, including 5 specimens of artificially melted diabase glass, were studied at temperatures up to 600°C. for the purpose of providing a more substantial physical basis for discussing the geological hypothesis of a vitreous basaltic layer. B.C.R.

Exchange adsorption of nickel by various minerals. I. I. GINZBURG AND A. I. PONOMAREV. *Izvest. Akad. Nauk S.S.S.R., Ser. Geol.*, **1940**, No. 2, pp. 161–82; *Khim. Referat. Zhur.*, **4** [3] 23 (1941).—The adsorption of Ni by approximately 50 minerals was studied. The results showed that Ni^{++} and also Cu^{++} and Fe^{++} displaced Ca^{++} and Mg^{++}. The adsorbed amount of Ni is equivalent to the bases displaced; it increases sharply, however, with an increasing $SiO_2 : R_2O_3$ ratio. The adsorption of Ni by penninite, beidellite-montmorillonite, ferri-beidellite, ferri-montmorillonite, hydrated Mg silicates, wad, and psilomelane is particularly great. Adsorption by talc, göthite, bauxite, etc., is weak or is entirely absent. Only the exchangeable bases are replaced in a mineral, not all the bases it contains. The exchange adsorption of Ni is irreversible. The results obtained confirm the field observations, e.g., the presence of Ni in the weathered parts of penninite, halloysite, montmorillonite, etc., and its absence in talcs, clinochlorites, etc. The lattice structure of the minerals is assumed to be of paramount importance in the exchange adsorption. M.Ho.

Galenite in the Permian deposits of Tatary. L. M. MIROPOL'SKIĬ. *Izvest. Akad. Nauk S.S.S.R., Ser. Geol.*, **1940**, No. 3, pp. 157–64; *Khim. Referat. Zhur.*, **4** [3] 27 (1941).—M. describes several new deposits of galenite in the Permian formation in Tatary. These are near the village of Kamskie Polyany on the left bank of the river Kama, near the villages of Pondyki and Bet'ki. The first and the third of these deposits are associated with limestone. In the cracks and joints of the latter, galenite is found along with calcite, chalcopyrite, and pyrite. The second deposit is connected with sandstone containing $CaCO_3$ in which the galenite is found associated with calcite and pyrite. Galenite is usually of later origin than pyrite and other sulfides. After studying the condition of its deposition, M. concludes that the genesis of galenite in the Permian deposits of Tatary is connected with the infiltration of water vapors containing Pb. The separation of Pb in the form of galenite is connected with a lowering of the oxidation potential of the medium. This in turn is caused by the presence of decomposing vegetable matter and an increase in the pH of the medium, resulting from the presence of $CaCO_3$. The source of the Pb in the solutions is not clear. M.Ho.

Geochemistry. ANON. *Ind. Bull. of A. D. Little, Inc.*, No. 180 (July, 1942).—The present war situation has placed great demands on the mining industry for increased supplies of manganese, chromite, tin, tungsten, and other materials. The geochemist has had to use his ingenuity to explore new sources and deposits of these strategic materials. Geochemical principles which have helped are as follows: (1) Metallic and ionic (or dissolving) substances each tend to stick together in their own class or geochemical affinity group, probably because of space lattices of crystals which act as sieves. (2) In igneous rocks such as granite, which were formed from molten matter, the physicochemical properties of the atoms and ions regulate the distribution of elements and minerals. (3) In such sedimentary rocks as sandstone or shale, deposited from solids eroded from older rocks, distribution of chemical elements is mainly determined by the physical properties of the fragments. (4) The concentration of elements or minerals is aided by the life processes of plants and animals. R.H.B.

Glass from cosmic space. F. HANSEN. *Diamant*, **63** [13] 95 (1941).—In 1787, in a limited district in Bohemia and Moravia, small stones were found which, from their appearance, were taken to be of green glass because of their amorphous nature and remainders of an ancient glass art in this district. When stones of similar composition were found in the Sunda Isles (around 1870) and Australia (1890), however, it was recognized that the view formerly held and the view that it might be material erupted by volcanoes were erroneous and that the little pear-shaped vitreous bodies had come from outer space as the oldest meteorites yet known. The geologic layers in which they were found in all three localities had an age of several million years. The very hard glasslike material could withstand chemical attack for centuries, while ordinary meteoric stones were destroyed. M.Ha.

Gold and its scope in industry. E. DOWNS. *Chem. & Ind.*, **61** [14] 156–59 (1942).—The industrial applications of gold are discussed in a general manner. Green, blue, and purple alloys are obtainable by additions of cadmium, iron, and aluminum, respectively. Gold has the desirable properties of high electrical conductivity, noncorrosiveness, thermal resistance, workability, and filming adaptability. It is used for plating, leafing, filming by cathode sputtering, rolling, imparting color to ceramic ware internally and externally, laboratory apparatus, X-ray science, medical therapy, and luxury. D. stresses the need

for a lend-lease program of gold to aid the manufacturer of vital war materials. R.H.B.

Heating and specific gravity curves of synthetic borates. A. G. CHELISHCHEVA. *Compt. Rend. Acad. Sci. U.R.S.S.*, **28** [6] 508–11 (1940); *Khim. Referat. Zhur.*, **4** [3] 20 (1941).—Heating curves were recorded on a Kurnakov pyrometer comprising both direct and differential thermocouples. The heating was regulated automatically with a potential regulator. Heating curves were recorded for $CaO \cdot B_2O_3 \cdot 6H_2O$ (monoborate), $2CaO \cdot 3B_2O_3 \cdot 13H_2O$ (inyoite), $CaO \cdot 3B_2O_3 \cdot 4H_2O$ (triborate), $2MgO \cdot 3B_2O_3 \cdot 15H_2O$ (inderite), $Mg_2B_4O_7 \cdot 9H_2O$ (diborate), $MgO \cdot 3B_2O_3 \cdot 7.5H_2O$ (triborate), and native inyoite and inderite. The following thermal effects are characteristic for all the borates: (1) 1, 2, or 3 endothermal effects are observed below 450° and are connected with the loss of H_2O; (2) an endothermal effect of unknown nature is observed at 630° to 685°; and (3) an exothermal effect is observed at 630° to 740°; for Mg diborate and synthetic inderite, there is a second exothermal effect at 725° (750°). The specific gravity of borates increases as a result of heating. It increases still more following the exothermal effect which, according to A. V. Nikolaev, is connected with a transformation of the amorphous borate into a crystalline state. M.Ho.

Idiomorphic cordierite crystals from Safe Harbor, Pennsylvania. W. HAROLD TOMLINSON. *Amer. Mineralogist*, **27**, 646–48 (1942).—A basaltic magma invaded a schist in Triassic time. The schist formed the aureolitic minerals orthoclase, cordierite, biotite, hercynite, rutile, and sillimanite. The chemical composition of the schist did not change. The cordierite crystals generally range from 0.002 to 0.004 mm. across the prism faces. Some show polysynthetic twinning. W.D.F.

Increased production of domestic chromium sought by Bureau of Mines. ANON. *Steel*, **111** [3] 56 (July 20, 1942).—Two processes which appear destined to increase the domestic output of chromium are as follows: (1) a beneficiation process for low-grade ores which so far has successfully passed all tests and has proved to merit large-scale pilot tests to determine the best operating conditions for commercial use and (2) an electrolytic method for recovering high-grade chromium from domestic ores. H.E.S.

Inesite, $Mn_7Ca_2Si_{10}O_{28}(OH)_2 \cdot 5H_2O$. W. E. RICHMOND. *Amer. Mineralogist*, **27**, 563–69 (1942).—X-ray measurements on a cleavage fragment gave $a_0 = 8.89$, $b_0 = 9.14$, $c_0 = 12.14$; $a_0:b_0:c_0 = 0.973:1:1.328$; $\alpha = 87°38'$, $\beta = 132°30'$, $\gamma = 97°06'$. This new orientation has been selected to make the direction of elongation the c axis and to retain the similarity inesite shows to members of the wollastonite group. Inesite is shown to be closely related to a high calcium rhodonite which theoretically may be considered as a dehydrated inesite. From published analyses and a new specific gravity determination, together with the lattice constants, the cell formula is calculated to be $Mn_7Ca_2Si_{10}O_{28}(OH)_2 \cdot 5H_2O$. W.D.F.

Laws of ionic exchange and their application to the ion exchange of soils. B. P. NIKOL'SKIĬ. *Byull. Khim. Obshchestva im. Mendeleeva*, **1940**, No. 9, pp. 6–8; *Khim. Referat. Zhur.*, **4** [3] 42 (1941). M.Ho.

Mineralogical composition of Mesozoic bauxites in Central Asia. A. D. SMIRNOV. *Izvest. Akad. Nauk S.S.S.R., Ser. Geol.*, **1940**, No. 3, pp. 114–24; *Khim. Referat. Zhur.*, **4** [3] 24 (1941).—The bauxites of Maĭlisaĭsk and Kishtutsk deposits of Jurassic origin are characterized by a compact structure in consequence of their appreciable metamorphosis. The alumina (30 to 35%) is found primarily as monohydric gel and its crystalline analogue, diaspore, and to a small extent as kaolin. The Fe is tied up as hematite and, to a lesser extent, as göthite. The silica (5 to 10%) is found either as a gel or as an integral part of the kaolinitic molecule. Ti (4 to 7%) is not found as an independent mineral but as a component of complex coagulum. The Jurassic bauxites of the eastern slopes of the Ural Mountains, Mugodzhar, Kazakstan, and southern Siberia are unlike the previously mentioned bauxites, having a loose and weakly cemented structure. The alumina (40 to 50%) in them appears as hydrargillite of trihydrous gel. The silica is tied up with terrigenous quartz. M.Ho.

Minerals from the Varuträsk pegmatites: XVI, Lithiophilite, a third primary alkali manganese phosphate of Varuträsk. PERCY QUENSEL. *Geol. Fören. Förh.*, **62**, 291–96 (1940).—Lithiophilite forms yellow-green grains and is colorless in thin sections. Cleavage after (001) and (010) is well displayed. The indices of refraction were determined to $n_{alpha} = 1.660$, $n_{beta} = 1.678$, gamma − alpha = 0.018, $2E_{Na} = 64°18'$. The chemical analysis gave the following values: insoluble 10.3, Li_2O 6.7, Na_2O 2.4, K_2O 0.5, FeO 6.4, MnO 29.9, CaO 3.0, P_2O_5 40.5, and H_2O 0.3% (sum 100%). The analysis showed that the ratio of $Li_2O:MnO:P_2O_5 = 0.94:1.97:1.00$, corresponding to the formula $LiMnPO_4$ or $Li_2O \cdot 2MnO \cdot P_2O_5$. **XVII, Further observations on the minerals varulite and alluaudite.** *Geol. Fören. Förh.*, **62**, 297–302 (1940); abstracted in *Chem. Zentr.*, **1941, I**, 1933.—Two new analyses of varulite from the Varuträsk deposits were made. The first analysis yielded MnO 25.31, FeO 11.03, Fe_2O_3 5.32, Al_2O_3 0.00, P_2O_5 44.93, TiO_2 0.00, CO_2 0.00, Cl traces, and F 0.00% (sum 99.97%). The following formula was evolved from the analysis: $[(Na, Mn^{II}, Fe^{II})\ Fe^{III}]\ PO_4$. A new analysis of alluaudite yielded P_2O_5 42.76, Fe_2O_3 16.44, Al_2O_3 0.00, Mn_2O_3 0.00, FeO 1.98, MnO 26.24, MgO 0.00, CaO 2.16, Li_2O 0.28, Na_2O 6.94, K_2O 0.13, F_2 0.00, H_2O^+ 1.60, H_2O^- 0.88, and insoluble 0.54% (sum 99.95%). The following formula was derived from the analysis: $(Na, Mn^{II}, Fe^{III})PO_4 \cdot x(H,Na)_2O$. M.V.C.

New minerals discovered in 1938. O. M. SHUBNIKOVA. *Trudy Inst. Geol. Nauk, Akad. Nauk S.S.S.R.*, **1940**, Ser. 31, Min.-Geol. Ser. No. 6, pp. 31–62; *Khim. Referat. Zhur.*, **4** [1] 37 (1941).—New minerals discovered in 1938 are described. In most cases, where data are available, the chemical, physical, and crystallographic characteristics, as well as the chemical composition, are given. Literature references to each of the minerals are appended. M.Ho.

Origin of shapes of quartz sand grains. EARL INGERSON AND JOSEPH L. RAMISCH. *Amer. Mineralogist*, **27**, 595–606 (1942).—The quartz grains in many metamorphic rocks tend to be elongate parallel to the c axis. Recently a similar elongation in the quartz grains of unmetamorphosed sandstones and another elongation parallel to the unit rhombohedron have been observed. Current explanations ascribe these elongations to fractures parallel to these directions and differential abrasion during transport. To check these explanations, three sets of experiments were carried out with the following results: (1) There was a decided tendency for some samples of quartz to fracture parallel to the unit rhombohedron, but no sample showed a pronounced fracture parallel to the c axis. (2) Quartz grains from weathered but undisturbed quartzose igneous and metamorphic rocks show a tendency to be elongate parallel to prism and unit rhombohedral faces. (3) Abrasion tests on oriented prisms show that quartz is harder on prism faces than normal thereto. It is concluded that the elongation of quartz sand grains is due to original shape rather than to fracture and differential abrasion during transport. W.D.F.

Particle-size studies. Methods. H. E. SCHWEYER. *Ind. Eng. Chem., Anal. Ed.*, **14** [8] 622–32 (1942).—The hydrometer, pipette, and Wagner turbidimeter methods for determining particle-size distribution in the subsieve size ranges were studied in detail. The results obtained on a variety of ground materials indicate that the hydrometer and pipette methods give concordant data which are also in agreement with those obtained by air elutriation. On the basis of these results, a special pipette for rapid analysis was designed. Using a special technique for size distributions down to 1.25 microns, it is shown that the Wagner turbidimeter gives good results only for ground sand, silica, and certain cements. The data obtained with the Wagner method for other materials were unsatisfactory on a basis of both specific surface and size distribution. The poor results by the turbidimeter on certain materials were shown to be caused by the lack of validity of the empirical conversion of turbidity data to weight concentration; this is of such magnitude that it limits the use of the apparatus to ground silica and certain cements. Illus-

trated. See "Symposium . . .," *Ceram. Abs.*, **21** [4] 92 (1942). F.G.H.

Probable new bentonitic clay horizon in Eocene of west Tennessee. GEORGE I. WHITLATCH. *Jour. Tenn. Acad. Sci.*, **17** [3] 280–84 (1942).—Bentonitic horizons in the clastic sediments of west Tennessee have not heretofore been described, although several metabentonite horizons have long been recognized in certain Ordovician limestone formations of middle and east Tennessee. W. describes a newly discovered locality, near Glass in Obion County, in which bentonitic clay occurs at or near the top of the Eocene (Tertiary) section of west Tennessee. See "Clays . . .," *Ceram. Abs.*, **21** [7] 154 (1942). G.I.W.

Problem of the adhesion of mineral particles to air bubbles. O. S. BOGDANOV AND M. SH. FILANOVSKIĬ. *Zhur. Fiz. Khim.*, **14** [2] 244–48 (1940); *Khim. Referat. Zhur.*, **4** [3] 12 (1941).—Photomicrographs of mineralized air bubbles are presented. The mineralized air bubbles were obtained by shaking a suspension of lead glance in an aqueous solution of butyl xanthate (50 mgm. per liter) using pine oil (30 mgm. per liter) as foamer. It was found that the adhering mineral particles do not deform the air bubble and do not penetrate it. Rapid photomicrographs of air bubbles in the above suspension were also prepared. On the basis of these photographs, the coefficient of gliding resistance of a mineral particle on the upper hemisphere of a stationary air bubble was calculated. The problem of deformation of a mineralized air bubble as affected by the dimensions of the bubble and the size of the mineral particle is discussed. M.Ho.

Rapid methods of grain-size measurements in pottery practice. S. W. RATCLIFFE AND H. W. WEBB. *Trans. Brit. Ceram. Soc.*, **41** [3] 51–70 (1942).—The merits of various methods of grain-size measurement are discussed together with results of experimental work on ground-flint particle size by the Andreasen sedimentation method. R.A.H.

Rapid qualitative test for tellurium. HATFIELD GOUDEY. *Amer. Mineralogist*, **27**, 592 (1942).—A small high form porcelain crucible is reclined in a cavity in a charcoal block. A small fragment of the material to be tested is placed inside near the rim. The fragment is gently reduced with a blowpipe flame. If tellurium is present it forms a lustrous black sublimate inside the crucible. To confirm this test, the fragment is removed and a drop of concentrated sulfuric acid is added to the still hot crucible; this forms the familiar reddish-violet coloration. W.D.F.

Studies of clay particles with the electron microscope: II, Fractionation of beidellite, nontronite, magnesium bentonite, and attapulgite. C. E. MARSHALL, R. P. HUMBERT, B. T. SHAW, AND O. G. CALDWELL. *Soil Sci.*, **54** [2] 149–58 (1942).—Fractions of each of these minerals were examined under the electron microscope, by means of which their crystal habit was learned and their particle dimensions were measured. These dimensions were related to settling velocities. N.R.S.

Study of sections of dolomitized limestones with the aid of reflected light. D. S. BELYANKIN, V. V. LAPIN, AND I. A. OSTROVSKIĬ. *Izvest. Akad. Nauk S.S.S.R., Ser. Geol.*, **1940**, No. 2, pp. 155–60; *Khim. Referat. Zhur.*, **4** [3] 24 (1941).—A study of polished sections of Kuibyshev dolomitized limestones in reflected light effectively aided in the investigation of the porosity, microstructure, and quantitative relations of calcite and dolomite. The results obtained by this method can be used to evaluate the structural properties of these materials. HCl (2%), H_2O, a saturated solution of gypsum, and a solution of $Ca(OH)_2$ were used for etching. Dolomite is not affected by these reagents. Calcite is affected by pure H_2O, only weakly affected by the gypsum solution, and not at all affected by the $Ca(OH)_2$ solution. M.Ho.

Twenty-five degree isotherm of the systems CaO–B_2O_3–H_2O and MgO–B_2O_3–H_2O. A. V. NIKOLAEV AND A. G. CHELISHCHEVA. *Compt. Rend. Acad. Sci. U.R.S.S.*, **28** [2] 123–26 (1940); *Khim. Referat. Zhur.*, **4** [3] 19–20 (1941).—Equilibrium was established very slowly, several months being frequently necessary. The solubility isotherm for the Ca system has several branches, the solid phases being $Ca(OH)_2$, $CaO \cdot B_2O_3 \cdot 6H_2O$ (monoborate) $2CaO \cdot 3B_2O_3 \cdot 13H_2O$ (inyoite), $CaO \cdot 3B_2O_3 \cdot 4H_2O$ (triborate), and H_3BO_3. Lines corresponding to $CaO : P_2O_3$ = 1:1, 2:3, and 1:3 cut the branches of monoborate and inyoite. The minimum solubility is found in the inyoite branch and corresponds to $B_2O_3/CaO = 9$. The isotherm of the Mg system has the following branches: $Mg(OH)_2$, $2MgO \cdot 3B_2O_3 \cdot 15H_2O$ (inderite), $MgO \cdot 2B_2O_3 \cdot 9H_2O$ (diborate), $MgO \cdot 3B_2O_3 \cdot 7.5H_2O$ (triborate), and H_3BO_3. All three of the singular lines cut through the branch of inderite. The minimum solubility on the inderite line corresponds to $B_2O_3/MgO = 7.74$. The solid phases were studied crystallographically and optically. The constants of synthesized and of native minerals are the same. The possibility of applying the same methods, i.e., solubility, for investigating quaternary systems of K, Na, Ca, Mg, and B_2O_3 is pointed out. The time required to attain equilibrium would, however, be measured in years. M.Ho.

BOOKS AND SEPARATE PUBLICATIONS

Chrome Resources of Cuba. T. P. THAYER. *U. S. Geol. Survey Bull.*, No. 935-A, 74 pp. Supt. of Documents, Govt. Printing Office, Washington, D. C. Price $1.00.—Total imports of Cuban chromite into the U. S., which are the best index of its production, amounted to 710,069 long tons up to the end of 1940. Of this, about 600,000 tons came from the Camaguey district, about 100,000 tons from eastern Oriente, and about 10,000 tons from Matanzas Province. Approximately 100,000 tons was of metallurgical grade, the remainder being of refractory grade. The chromite deposits are irregular masses containing from a few tons to over 100,000 tons of shipping-grade ore in belts of serpentinized peridotite along the north coast for nearly the entire length of Cuba, but production has been limited to the eastern half of the Island. Workable deposits of residual or float ore have been formed in some areas of low relief. Pure chromite from Cuba contains from 22 to 57% chromic oxide and 9.7 to 14.4% iron. The reserve of shipping-grade lode ore within 100 ft. of the surface in the Camaguey district probably approaches 500,000 tons. The known reserves of eastern Oriente are about 200,000 tons of milling- and shipping-grade ore. R.A.H.

Chromite and Quicksilver Deposits of the Del Puerto Area, Stanislaus County, Calif. H. E. HAWKES, JR., F. G. WELLS, AND D. P. WHEELER, JR. *U. S. Geol. Survey Bull.*, No. 936-D. Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 30¢.—The Del Puerto chromite and quicksilver area is in western Stanislaus County in the central part of the coast range of California. The chromite occurs almost exclusively in dunitic members of the ultrabasic complex. Most of the commercial deposits consist of pods and irregular bodies of massive high-grade granular chromite in zones of shearing. The only mine at which a fair tonnage of ore is in sight at the present time is the Black Bart, where 1200 tons have been blocked out. Further explorations of this deposit may uncover at least another 1000 tons. Most of the ore bodies were mined out during 1916 to 1918, and there is no reason to believe any large deposits will be discovered. R.A.H.

Diamond and Gem Stone Industrial Production. PAUL GRODZINSKI. N. A. G. Press, Ltd., London. 256 pp., 183 illustrations. Price 15s, cloth binding. Reviewed in *Can. Machinery*, **53** [6] 206 (1942).—P. discusses the selection, cutting, polishing, and drilling of diamonds and gem stones for industrial purposes. E.D.M.

Geology of Quebec: Vol. 1, Bibliography and Index. JOHN A. DRESSER AND T. C. DENIS. Dept. of Mines, Quebec, 1942. Price $1.00. Reviewed in *Can. Mining & Met. Bull.*, No. 362, p. 218 (1942); *Can. Mining Jour.*, **63** [6] 388 (1942). G.M.H.

Manganese Investigations—Metallurgical Division: 16, Ore-dressing studies of manganese ores. Beneficiation of oxide manganese ores from Las Vegas, Nev. S. R. ZIMMERLY, C. H. SCHACK, AND F. E. THACKWELL. *U. S. Bur. Mines Repts. Investigations*, No. 3647, 25 pp. Free. R.A.H.

Muscovite in the Spruce Pine District, N. C. T. L. KESLER AND J. C. OLSON. *U. S. Geol. Survey Bull.*, No. 936-A. Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 35¢.—The Spruce Pine District has had an average production of about 45,000 lb. a year of relatively clear sheet mica since 1924. Some of this is apparently as good as the higher grades of imported mica used in the manufacture of radio equipment, airplane spark plugs, transformers, and generators. The Spruce Pine mica is mined from pegmatite bodies that range from a few inches to more than 100 ft. in thickness. The occurrence of the mica and its physical properties are described. R.A.H.

Sodium Carbonate. CHARLES L. HARNESS AND A. T. COONS. *U. S. Bur. Mines Information Circ.*, No. 7212, 35 pp. Free.—Sodium carbonate and its production, consumption, uses, and history are described. The geologic occurrence and methods of recovering natural sodas, the manufacture of soda ash, and foreign trade, tariffs, prices, and the industry in foreign countries are discussed. R.A.H.

Topaz Deposits near the Brewer Mine, Chesterfield County, S. C. *U. S. Geol. Survey Bull.*, No. 936-C (1942). Supt. of Documents, Govt. Printing Office, Washington, D. C. Price 30¢.—Lode and placer deposits of massive topaz rock were discovered near the old Brewer gold mine in northwestern Chesterfield County, S. C., in 1935. Preliminary tests showed that this rock can be used in the manufacture of refractory ware and as a source of mullite, thus augmenting supplies of kyanite that have been coming from India. The country rock in the region is a quartz-sericite schist, which is, in some places, completely silicified. Part of the topaz is in some of this silicified rock that extends northwest from the old Brewer open pit. The district contains probable reserves amounting to about 106,000 tons of rock averaging at least 15% topaz. In addition there are probable reserves of about 194,800 tons of topaz-bearing rock of the same grade. R.A.H.

PATENTS

Beneficiation of manganese ores. DANIEL GARDNER. U. S. 2,296,841, Sept. 29, 1942 (March 1, 1941).

Gravity separation of ores. H. H. WADE (Minerals Beneficiation, Inc.). U. S. 22,191, Sept. 29, 1942 (June 25, 1941); reissue of original U. S. 2,206,980, July 9, 1940 (March 31, 1938).

Separation of feldspar from quartz. R. G. O'MEARA (Government of the United States of America, as represented by the Secretary of the Interior). U. S. 2,297,689, Oct. 6, 1942 (April 5, 1940).—The process of separating aluminous silicate minerals of the group consisting of feldspars and kyanite from comminuted mixtures thereof with quartz consisting in forming a slurry of the mixture with water, a cationic flotation reagent yielding long chain cations containing from 12 to 19 carbon atoms, and a modifying agent consisting of hydrofluoric acid in which may have been dissolved multivalent metal oxides from traces to almost complete neutralization of the acid and separating the aluminous silicate minerals by flotation.

Chemistry and Physics

Boundary-surface phenomena with silica gels. RUDOLF KÖPPEN. *Kolloid.-Z.*, **89** [2] 219–23 (1939).—The disappearance of hydroxyl ions from weakly alkaline solutions containing silica gel on the addition of neutral salts, as well as the reappearance of these hydroxyl ions on washing the gels, indicates the covering of one of the two layers bounding the gel particle with hydroxyl ions. This layer is brought into solution by the addition of an electrolyte, as the theory of electrically charged boundary layers in dissociated liquids requires. The relation of the pH to the amount of alkali added to the solution surrounding the gel indicates a chemical adsorption of the alkali on the boundary surfaces of the silica gel. It is unnecessary to assume a specific effect of the surface to explain the saponifying catalysis of the silica gel because the hydrogen or hydroxyl ions are always adequate in the capillary system. If the hydroxyl ions are only partially replaced by the anions of strong inorganic acids, the surface activity characteristics of the silica gel appear to change, as is shown in the example of the reduction of silver on the boundary surfaces of the gel. The adsorption of dyes from solutions by the silica gel may be explained by the presence of the double ionic layer on the boundary surfaces of the gel. It is unnecessary to assume any special affinity of the dye for the gel. W.H.H.

Colorimetric method for phosphates. L. S. STOLOFF. *Ind. Eng. Chem., Anal. Ed.*, **14** [8] 636–37 (1942).—S. presents a modification of the Association of Official Agricultural Chemists molybdenum-blue method for the colorimetric determination of phosphates. Illustrated. F.G.H.

Determination of calcium in the presence of magnesium by standard soap solution. Rapid titration method. J. W. POLSKY AND E. C. FEDDERN, W. H. & L. D. BETZ. *Ind. Eng. Chem., Anal. Ed.*, **14** [8] 644–46 (1942).—Calcium in water can be determined in the presence of magnesium by direct titration with Clark's soap solution with the addition of ammonium chloride and with pH adjustment. Ions common to industrial waters do not interfere. The accuracy and rapidity of this method are equivalent to those of the usual soap titration for total hardness. Illustrated. F.G.H.

Determination of magnesium in dolomite. R. FOUQUET AND L. CAPDECOMME. *Compt. Rend.*, **211** [24] 652–54 (1942).—A simple method has been developed for determining the content of magnesium in dolomite, which often varies considerably even in samples of the same origin. The sample is dissolved in H_2SO_4 and neutralized with $CaCO_3$. The Mg content of this solution is measured by its electrical conductivity which is a linear function of the Mg content. The method is said to be equally well suited to prospecting and to plant or laboratory use. An example is given. M.HA.

Dimensionless quantities in thermodynamics. C. KÄMMERER. *Wärme*, **64** [10] 117–18 (1941).—By introducing, as a new fundamental unit, the mole in the place of temperature and considering temperature as molecular energy, K. shows that the dimensional formulas of temperature, specific molecular heat, mole entropy, molecular evaporation entropy, and molecular surface energy become dimensionless; in this way it is possible to arrive at an equation of state identical for all substances without individual constants. The absolute temperature (°K.) of a gas is defined as the mean kinetic energy of the progressive or translatory energy of the center of gravity of the molecule. The derivation of the equations for these quantities is given. M.HA.

Electric furnace boroaluminate. H. N. BAUMANN, JR., AND C. H. MOORE, JR. *Jour. Amer. Ceram. Soc.*, **25** [14] 391–94 (Oct., 1942).—5 references, 3 figures.

Electrochemical properties of mineral membranes: I, Estimation of potassium-ion activities. C. E. MARSHALL AND W. E. BERGMAN. *Jour. Amer. Chem. Soc.*, **63**, 1911–16 (1941); *Chem. Abs.*, **35**, 5772 (1941).—The technique employed in obtaining the membrane potentials was similar to that used by Marshall (*Jour. Phys. Chem.*, **43**, 1155–64 (1939)). The activities were estimated by means of the equation of Meyer and Sievers (*Helv. Chim. Acta*, **19**, 649–64, 665–77 (1936)) and of Teorell (*Trans. Faraday Soc.*, **33**, 1054 (1937)) for the potential across a membrane separating two solutions of the symmetrical-valence type. Data are given for the charge on the following membranes (expressed as an ionic activity) as related to the temperature of drying: Ca, H, and K bentonite; for the membrane (bentonite) potentials with the salt solutions $CaCl_2$ and $MgSO_4$; and for the effect of pH and large anions (acid phthalate, *p*-toluenesulfonic acid, and *p*-nitrophenol). The results indicate that K^+ activities can be determined

in the absence of other univalent cations with a precision within 5% at pH values above 4. A high degree of reproducibility is possible with commercial Wyoming bentonite from which all particles larger than 200 mμ in equivalent spherical diameter have been removed by supercentrifuging. Preliminary experiments indicate that bentonite membranes can serve as electrodes for the determination of other univalent cations. The results with Na appear promising. Search is being continued for membrane materials that will serve as electrodes for the determination of bivalent cations. Apophyllite membranes are difficult to prepare and show a variable behavior with K. For Part **V** see *Ceram. Abs.*, **21** [10] 223 (1942).

Estimation of magnesium with 8-hydroxyquinoline. Microtitration and photometric procedures. LOUIS GERBER, RALPH I. CLAASSEN, AND C. S. BORUFF. *Ind. Eng. Chem., Anal. Ed.*, **14** [8] 658–61 (1942).—The determination of magnesium by precipitation with 8-hydroxyquinoline and oxidation of the organic part of the precipitate with ammonium hexaperchlorato cerate was found to be applicable to amounts of magnesium as small as 5 μgm. The factors 59.5 for the equivalents of cerate per mole of magnesium and 29.8 for the equivalents of cerate per mole of 8-hydroxyquinoline were reproducible when oxidation was carried out at 95° to 100°C. for not less than 15 min. and with a cerate reagent 0.05 *N* or less at a perchloric acid concentration of 2 molar. Ceric sulfate proved much inferior to the perchlorato cerate in rate and extent of oxidation of 8-hydroxyquinoline. The conditions for the development and characteristics of the color produced when ferric chloride is added to a solution of the magnesium hydroxyquinolate in 1% acetic acid are described. In the range 5 to 100 μgm., the solution obeys Beer's law. The advantages of the photometric procedure are the elimination of standard solutions that require relatively frequent restandardization, fewer operations once the washed precipitate has been prepared, and greater precision than the microtitration technique. By means of the centrifuge, all steps from the first precipitation up to the final reading in the photometric instrument are carried out in the same tube, thereby avoiding transfer losses and minimizing the correction for the blank. Illustrated.

F.G.H.

Frictional phenomena: VIII, Structural viscosity. ANDREW GEMANT. *Jour. Applied Physics*, **13** [4] 210–21 (1942).—Gel formation in colloidal systems causes their viscosity to vary with stress. Because the physical cause is related to the gel structure, the phenomenon is called structural viscosity. The chief experimental facts are presented, together with semitheoretical equations suitable for describing the experiments. **IX, Applications of liquid viscosity to electrical insulating liquids, particularly in high-voltage cables.** *Ibid.*, [5] 290–99.—G. discusses the mechanical and chemical problems involving viscosity and electrical conductivity in connection with liquid dielectrics. **X, Lubrication.** *Ibid.*, [6] 355–60.—The application of the viscosity concept to lubrication is presented under film lubrication (film thickness greater than 10^{-5} cm.) and boundary lubrication (layers less than 10^{-5} cm. thick). The first is controlled chiefly by the viscosity of the liquid. The second is essentially a plastic flow within the boundary. For Part **VII** see *Ceram. Abs.*, **21** [6] 132 (1942). A.P.

High-index medium for rapid impregnation of friable materials. C. P. KAISER AND H. T. U. SMITH. *Amer. Mineralogist*, **27**, 590–91 (1942).—Aroclor 4465 is suggested for this use as it has a low viscosity and will impregnate materials that are not too impervious by capillary action and without the use of a solvent. Its index of refraction is 1.66+. W.D.F.

Interaction within the limits of the system $(Na, K)_2O$–Al_2O_3–SiO_2–CaO on fusion. F. N. STROKOV, V. A. MUSIAKOV, AND E. YA. ITKINA. *Sbornik Rabot Gosudarst. Inst. Priklad. Khim.*, **1940**, No. 32, pp. 87–95; *Khim. Referat. Zhur.*, **4** [1] 107 (1941).—The interaction of the system R_2O–Al_2O_3–SiO_2–CaO was studied to find a method for the maximum conversion of the Al_2O_3 of nepheline calcination products into an alkali-soluble form. A nepheline charge of standard composition was calcined in an electric furnace, and the product was leached with a solution of Na_2CO_3 + NaOH. When the temperature is increased from 1000° to 1300°, the porosity of the product diminishes and the amount of Al_2O_3 extracted increases from 81 to 92% and tends to attain its maximum at fusion. An attempt to increase the basicity of the mixture R_2O-Al_2O_3, which favors a greater yield of Al_2O_3, by adding sodium metasilicate was unsuccessful. For a good extraction of Al_2O_3, calcination to clinker or fusion and a composition of the charge corresponding to $CaO:SiO_2 = 2$ and $R_2O:Al_2O_3 = 1$ are required. This is independent of the composition of the crude. M.Ho.

Investigation of the surface of colloidal particles of TiO_2 sols. V. V. KISELEVA AND V. A. KARGIN. *Acta Physicochim. U.R.S.S.*, **12** [4] 589–608 (1940); *Khim. Referat Zhur.*, **4** [1] 28 (1941).—The adsorption phenomena of colloidal particles and their various chemical influences were studied. The following method was employed: To a clear, colorless TiO_2 sol containing both positively and negatively charged particles, a colloidal pigment of the same or opposite sign was added. The adsorption spectra of these systems were studied upon the addition of either a coagulating substance in concentrations lower than the coagulating value or dispersing electrolytes. The following systems were studied: (1) TiO_2^+ + erythrosine, (2) TiO_2^+ or TiO_2^- + methylene blue, and (3) TiO_2^- + thionine. The adsorption spectrum changes appreciably when the TiO_2 sol is mixed with an oppositely charged pigment. When the signs are similar, the neutral color of the pigment is retained. In both cases the pigment is adsorbed by the TiO_2 sol and the observed colors are independent of the acidity of the suspension (pH 3.16). Upon the addition of coagulators (Na_2SO_4 was added for TiO_2^+, $BaCl_2$ was added for TiO_2^-) and dispersants (tartaric acid for TiO_2^-), the adsorption spectrum changed. Conclusions on the mechanism of adsorbed layers are given. M.Ho.

Manufacture of silica aerogel—description of process and heat-transfer problems. JOHN F. WHITE. *Trans. Amer. Inst. Chem. Engrs.*, **38** [3] 435–46 (1942).—The basic theory underlying the method of producing aerogels and a general description of the process are given. Particular attention is given to the heat-transfer problems, involving the heating of a SiO_2 alcogel to temperatures and pressures above the critical points for the liquid phase present in the gel. It is shown that the major portion of heat transfer is accomplished by convection, the amount being transferred by radiation and conduction being negligible in the pilot-plant autoclave described. The shapes of the isotherms existing in the autoclave and their rate of travel are given, supplying data useful for design purposes. The advantages of condensing diphenyl vapor for supplying heat at high levels to pressure vessels are discussed. H.E.S.

New methods of thermal analysis: a method for recording the heating curves. K. M. FEODOT'EV. *Trudy Mineralogii & Petrografii, Inst. Geol. Nauk, Akad. Nauk*, **1940**, 83–94; *Khim. Referat. Zhur.*, **4** [2] 57 (1941).—A method utilizing differential thermocouples is explained. A theoretical analysis of the method leads to the conclusion that the quantitative determination of the composition of a mineral (primarily sedimentary) depends on the use of proper heating conditions. The heating should be done at a slow rate, e.g., 5° to 6° per min. The sample should be such that the maximum absolute thermal effect should not exceed 550 cal. The quantitative determination is based on the measurement of the absolute thermal effect by determining the difference in temperature of two business ends of a differential thermocouple, one of which is placed in the sample and the other in an unchangeable standard. M.Ho.

Nomograms of optic angle formulas. JOHN B. MERTIE, JR. *Amer. Mineralogist*, **27**, 538–51 (1942).—M. presents nomograms for the solution of several well-known petrographic formulas that are used in the measurement of optic angles. To solve for any one of the four variables, α, β, γ, and V, when three of them are known, a grid type

nomogram has been prepared; a similar chart has been drawn to show the relationships between the variables α, β, γ, and E. Two nomograms are also presented for the solution of the equations $\sin E = \beta \sin V$ and $D = K \sin E$ (Mallard's formula). The method of preparing these charts is outlined, and their use is given. Errors in observations and computations are also considered. W.D.F.

Rapid volumetric method for the determination of sulfate ion. MERLE RANDALL AND HENRY O. STEVENSON. *Ind. Eng. Chem., Anal. Ed.*, **14** [8] 620–21 (1942).—The method suggested by Balakhovski and Ginsburg was proved unsatisfactory. Using disodium hydrogen phosphate as the titrating agent, a satisfactory and rapid method for sulfate and barium ions has been found. Barium chloride is added in excess to a sulfate-containing solution, and the excess is titrated to the methyl red end point with standard disodium hydrogen phosphate in an alcohol and water medium. With ordinary precision and in the hands of a competent analyst, the method may be expected to give results within 0.5% and to require 10 to 15 min. The method is applicable in control work, especially for the rapid determination of the sulfur content of oils and for rapid barium determinations. Illustrated. F.G.H.

Reactions between $CaCO_3$ and SiO_2 during heating and the hydrochemical treatment of the resulting compounds. F. N. STROKOV, V. A. MUSIAKOV, AND V. S. VOLKOV. *Sbornik Rabot Gosudarst. Inst. Priklad. Khim.*, **1940,** No. 32, pp. 41–48; *Khim. Referat. Zhur.*, **4** [1] 106 (1941).—$CaCO_3$ and SiO_2, in molar ratios of 1, 2, and 3, were calcined for 1 to 6 hr. at 1000° to 1450°. At the lower temperatures $3CaO \cdot 2SiO_2$ and β-$2CaO \cdot SiO_2$ were formed, which subsequently change to α-$CaO \cdot SiO_2$. Upon further increase of the temperature, the mixture becomes more basic, and in the absence of an excess of CaO the eutectic is formed. The addition of more than 2.5% Fe_2O_3 hastens the reaction. In the calcination of nepheline-lime mixtures using a standard charge of $2CaO:1SO_2$ (molar), the composition of the Na silicates should be mainly $CaO \cdot SiO_2$. Experiments on the leaching of Ca silicates conducted on specially synthesized compounds showed that the accepted procedure for leaching nepheline-lime calcination products yields only small amounts in the leachate. M.Ho.

Replacement of sodium in crystals of β-alumina with calcium, strontium, and barium. N. A. TOROPOV AND M. M. STUKALOVA. *Compt. Rend. Acad. Sci. U.R.S.S.*, **27** [9] 974–77 (1940); *Khim. Referat. Zhur.*, **4** [2] 80 (1941).—White corundum containing 4.5% Na_2O was ground through 4900 mesh per sq. cm. This was twice fused with a six-fold amount of Ba, Ca, or Sr chloride. As a result of the exchange of the alkaline earth for Na, the density and refractive index of the crystals were changed. X-ray pictures revealed a similarity between the products and between the products and the parent material. M.Ho.

Sodium silicate and hydrochloric acid from sand, salt, and steam. R. K. ILER AND E. J. TAUCH. *Trans. Amer. Inst. Chem. Engrs.*, **37,** 853–77 (1941).—Several proposed processes for the above reaction at elevated temperatures were examined. Low yields, previously believed due to mechanical difficulties, appear attributable to a rather unfavorable equilibrium constant. The equilibrium constant has been calculated from available thermodynamic data and confirmed experimentally by determining the composition of a mixture of HCl, water, and salt vapor from which a silica surface begins to absorb sodium oxide. For this reaction, $2NaCl\ (gas) + H_2O\ (gas) + SiO_2\ (glass) = Na_2SiO_3\ (liquid) + 2HCl\ (gas)$, where the equilibrium constant $K = (HCl)^2/(NaCl)^2(H_2O)$ and $\log_{10}K = +2.9$ at 1000°, +1.2 at 1200°, and +0.1 at 1400°K. Calculations based on these values indicate that the thermal efficiency of any salt, sand, and steam process operated above 1000°C. will be very low, due to the large amount of heat carried from the reaction zone by unreacted salt vapor. A high yield of acid, based on salt input, cannot be obtained simultaneously with the condensation of strong HCl. Operation of the process below 1000°C. does not appear practical because of the difficulty of recovering strong acid and because of the low rate of reaction. These results appear to preclude the use of this reaction for the commercial production of sodium silicate and HCl. **Discussion.** J. G. VAIL, A. H. MAUDE, AND A. E. MARSHALL. *Ibid.*, **38** [2] 245–46 (1942). E.D.M.

Thermal-expansion characteristics of some calcareous and magnesium minerals. G. R. RIGBY AND A. T. GREEN. *Bull. Brit. Refrac. Research Assn.*, No. 58 (March, 1941); reprinted in *Trans. Brit. Ceram. Soc.*, **41** [5] 123–43 (1942).—The expansion characteristics of several synthetic minerals are reported. These include the binary silicates of magnesia and lime, together with the ternary compounds akermanite, diopside monticellite, merwinite, cordierite, gehlenite, and anorthite. In the light of these results, the thermal changes occurring on heating three different steatites and an asbestos mineral are discussed. The thermal-expansion curve of anorthite showed a reversible inflection circa 800°C. which resulted in a marked increase in the expansion coefficients over the temperature range 750° to 900°C. The maximum that occurs in the expansion coefficients of fired fire-clay bodies around 800°C. can be satisfactorily attributed to the presence of a small percentage of anorthite in these materials. The thermal expansions of various dolomite products are recorded, including both a used and an unused brick and a sample taken from a dolomite hearth. An unexplained expansion which set in between 925° and 1200°C. was found to occur in the dolomite materials after various heat-treatments and also in the thermal decomposition products of a lime-bearing steatite and an asbestos mineral. R.A.H.

PATENTS

Fluorescent material. A. H. MCKEAG AND P. W. RANBY (General Electric Co.). U. S. 2,297,108, Sept. 29, 1942 (Jan. 30, 1942).—A phosphor comprising a matrix of alkaline earth metal silicate activated with europium and fluorescing in the color range of yellow, green, blue, and violet when excited by 3650-a.u. radiation.

Silicate treated titanium pigment. G. D. PATTERSON (E. I. du Pont de Nemours & Co.). U. S. 2,296,618, Sept. 22, 1942 (Feb. 2, 1939).—A process for treating a titanium dioxide pigment which comprises mixing with an aqueous slurry of the pigment about 1 to 10%, based on the weight of the pigment, of an alkali-metal silicate and thereafter adding to the slurry, as a precipitant, barium chloride, thereby precipitating an insoluble silicate in the presence of the pigment.

General

American Optical Co. ANON. *Bull. Amer. Ceram. Soc.*, **21** [9] 179–86 (1942).

Conserving power, air, and gas. F. S. KRIGER. *Factory Management & Maintenance*, **100** [8] 141–42 (1942).—A conservation program followed by Corning Glass Works is outlined. N.R.S.

Flexible, transparent, and translucent substitutes for window glass. R. J. MOORE AND H. W. MACKINNEY. *Trans. Amer. Inst. Chem. Engrs.*, **38** [1] 237–44 (1942).—Information on the suitability and availability of materials to replace window glass in case of air-raid damage is given. Self-supporting clear plastic films, transparent films supported on wire or textile meshes, woven fabric treated with translucent film-forming material, and paper are discussed. The best material readily available is considered to be a clear plastic film (cellulose acetate, ethyl cellulose, or a vinyl copolymer) supported by an open textile mesh. Recent developments in vinyl resin-treated fiber glass may make possible the use of glass cloth as a film support. 9 references. E.D.M.

Fundamentals of the testing of ceramic materials. RUDOLF BARTA. *Keram. Rundschau*, **45** [28] 309–14

(1937); see "Principles . . .," *Ceram. Abs.*, **16** [11] 360 (1937). M.V.C.

Industrial medicine and the workmen's compensation system. J. B. LAURICELLA. *Ind. Med.*, **11** [9] 415–19 (1942).—L. points out that industrial medicine has been present in some form or other since the beginning of civilization with the object, even in slave-labor eras, of returning sick and injured workers to usefulness again. Hippocrates, the contemporary of Plato and Socrates, was the first to recognize the toxic properties of lead. He reported many cases of lead colic as affecting lead miners. When miners became ill, he urged rest and palliative measures away from the place of work, which he felt to be the true cause of the disease. As prevention methods, he advocated physical exercises, baths, massage, and proper diet. His influence dominated medical practice for 500 years. In the 1st century A.D., Pliny the Elder disclosed the dangers inherent in handling sulfur and zinc. In one of his books, he speaks of masks made of transparent bladders worn by workmen in the preparation of vermilion to protect them against lung disease due to inhalation of this metallic dust. The history of compensation proper dates back to ancient Rome whose foreign legions received rewards for services and injuries in terms of property grants and gold. Through the centuries since, disabled soldiers have received additional property and grants of money on their return from war. K.R.

Law of patent infringement. LEO T. PARKER. *Combustion*, **14** [3] 51–53 (1942).—A suit for patent infringement involves three fundamental questions: (1) Has the patentee invented something? (2) Is the invention described in the specifications? (3) Is it covered by the claim? Such subjects as who may infringe, joint ownership, law of anticipation, process patents, etc., are discussed. H.E.S.

Prevention of heat sickness. INDUSTRIAL HYGIENE FOUNDATION MEDICAL COMMITTEE. *Mining Congress Jour.*, **28** [8] 25 (1942).—High temperatures have a pronounced effect on susceptibility to minor accidents. Heat sickness includes (1) heat cramps, (2) heat prostration, and (3) heat pyrexia. Heat cramps are caused by excessive loss of sodium chloride and may be relieved almost miraculously by injection of saline solution. It can be prevented by salt tablets. Heat prostration is a systemic collapse and is best treated by rest; other remedies recommended are glucose and other sweet things and Vitamin C. Heat pyrexia is sunstroke caused by failure of the heat-regulating system. The victim should be removed to a cooler place and treated for shock. See "Combating . . .," *Ceram. Abs.*, **21** [10] 225 (1942). W.D.F.

BOOKS AND SEPARATE PUBLICATIONS

Custom House Guide, 1942. Custom House Guide, Box 7, Station P, Custom House, New York, N. Y. Price $15. Reviewed in *Can. Machinery*, **53** [7] 113 (1942).—Each port in the U. S. and its limits, activities, and port charges are described, and a directory of those engaged in shipping and allied commerce trades is given. A general information section is devoted to weights, measures, coin values, trade terms, air services, government departments, etc. E.D.M.

Findings from major studies of fatigue. R. R. SAYERS. *U. S. Bur. Mines Information Circ.*, No. 7209, 46 pp. Free.—Under compulsion of the present urgency, there is a tendency to demand relaxation of restrictions on hours of labor and to speed up all industrial processes. Data on fatigue and health show clearly the relationship between fatigue and loss of working efficiency and increased accident occurrence, but there is little actual medical proof that long fatiguing periods of work permanently affect efficiency, health, or working capacity. A bibliography is included. R.A.H.

Manual for Committees of Engineers Interested in Engineering Education and the Engineering Profession. Engineers' Council for Professional Development, 29 West 39th St., New York, 1942. Price 10¢; appendix only, 5¢; discount on quantity orders.—Direct aids in counseling are given in outline form, and the advisors are urged to present their case in the form of (1) general talks to student bodies, (2) explanations of a more technical nature to small groups of boys having a definite interest in civil, electrical, or other branches of engineering, (3) essay contests limited to 500-word papers on the subject "Why I Believe I Should Be an Engineer," and (4) inspection trips and motion pictures, when practical. A list of books and pamphlets on vocational guidance, especially in relation to engineering, is given. Full information on the engineering field is made available to high-school students who will qualify for and are interested in engineering. The appendix is designed for use by the student in supplying biographical and educational background.

Symposium on Industrial Health. Medical College of Virginia, Department of Preventive Medicine, Richmond, Va., 1941. 129 pp., mimeographed. **Medical Society of Virginia's program for industrial health.** WALTER B. MARTIN. Pp. 1–2. **State Department of Health's Bureau of Industrial Hygiene—assistance it can render the industrial physician.** J. B. PORTERFIELD. Pp. 3–5. **Tuberculosis in industry—use of mass X-raying.** E. C. HARPER. Pp. 6–10. **How an industrial physician can and should cooperate with the general practitioner.** RUSSEL R. JONES. Pp. 11–15. **Respiratory diseases and air conditioning.** W. J. MCCONNELL. Pp. 16–22.—Statistical studies and medical experience indicate that over 50% of the illness of industrial workers is due to acute infections of the upper respiratory tract, especially the common cold. Time is lost by all concerned and at approximately a cost of a billion dollars annually. The author (the Assistant Medical Director of the Metropolitan Life Insurance Co.) reviews in turn various experiments intended to lessen these disease ravages among workers, but as long as the specific agents causing these several diseases are not definitely known, the experiments must continue. The contribution of the Metropolitan Life to the problem was to try out air conditioning. After studying their records, the author and his assistants moved half of their 10,000 workers over to the Company's new air-conditioned building, leaving the other half as controls in the older office building, ventilated only by raising the windows and without any artificial humidification or cooling supplied in hot, dry periods of the summer. To the surprise of the experimenters, the new records failed to show any appreciable difference in the number of attacks of respiratory illness per clerk, or the number of days lost per clerk among the two groups. However, the partial air conditioning now frequently employed, such as air filtration for persons subject to hay fever, pollen asthma, and other allergic diseases, has produced very satisfactory results. Another example of partial air conditioning occurs in the entrapment of air contaminated with unwanted gases, fumes, and dusts, and its subsequent removal through exhaust equipment and other devices, which are depended upon almost entirely for the protection of workers subjected to the dangerous concentrations of dust responsible for pneumoconioses and the irritant effects of other toxic by-products of industrial processes. **Diagnosis, treatment, and prevention of industrial dermatoses.** LOUIS SCHWARTZ. Pp. 23–35. **Essentials of first aid and later management of industrial eye injuries.** HARRY B. STONE. Pp. 36–42. **Handling of chemical burns of the eye.** GEORGE H. CROSS. Pp. 43–49. **Detection and control of defective vision in industry.** RUDOLPH C. THOMASON. Pp. 50–56. **Protective equipment for eyes in industry.** C. N. SCOTT. Pp. 57–61. **Diet and dietary deficiencies.** D. FRANK MILAM. Pp. 62–68. **Aging as a problem of industrial health.** EDWARD J. STIEGLITZ. Pp. 69–78. **Medical control of industrial exposure to toxic chemicals.** JOHN H. FOULGER. Pp. 79–91. **Placement of the worker.** T. LYLE HAZLETT. Pp. 92–96. **Suggestions for the conduct of hygiene departments in industry.** DONALD E. CUMMINGS. Pp. 97–100. **Selection of antiseptics for application to wounds.** THOMAS BEATH. Pp. 101–14. **Purposeful splinting following injuries to the hand.** H. C. MARBLE. Pp. 115–20. **Prevention and treatment of infections of the hand.** SUMNER L. KOCH. Pp. 121–26. **Backache.** H. PAGE MAUCK. Pp. 127–29.

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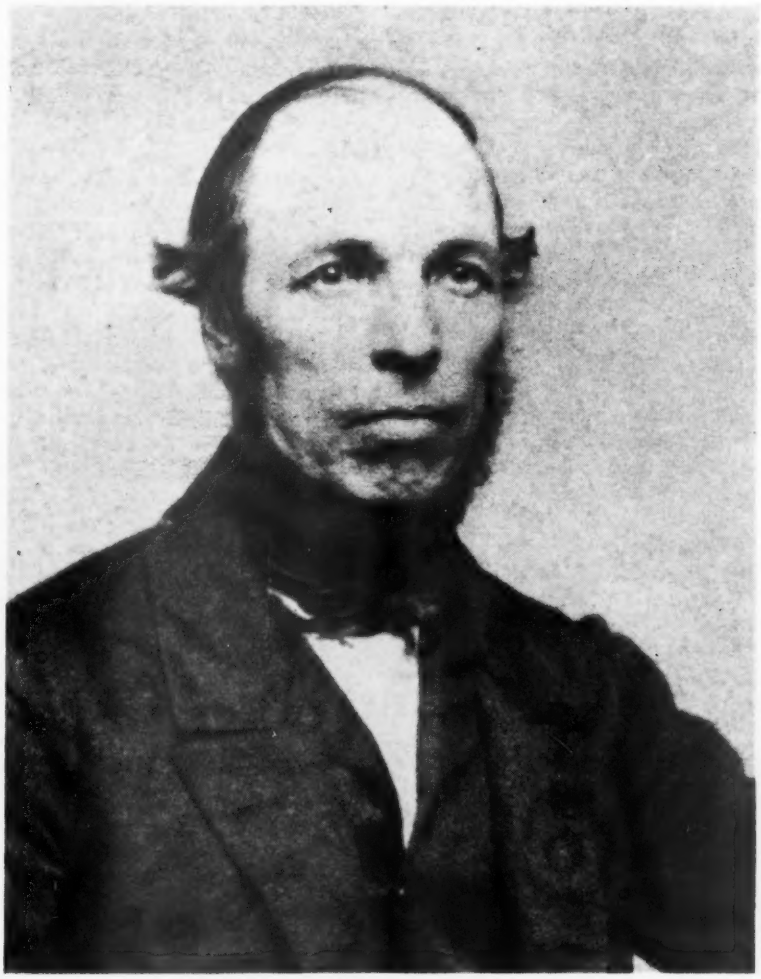

John Goodwin

THE STORY OF JOHN GOODWIN, PIONEER POTTER

By Lucille T. Cox

John Goodwin, one of the pioneer potters of America, was born in Burslem, England, in 1816. He worked in the James Edward Pottery in Dale Hull, Burslem, until 1842, when a strange event took place in his life.

During the opening years of the nineteenth century, England was faced with the problem of too many people. Her industrial towns were crowded centers of a teeming population living in filthy disease-ridden quarters. Compulsory emigration became the order of the day.

The potters in Burslem were each given a number. At

stated times, drawings were made, and the men possessing the called numbers were required to leave England in a fortnight or face life imprisonment. They could go to one of the English colonies or, by special permission, to America. John Goodwin's number was selected in January, 1842. He had no choice but to sell his belongings, poor and meager as they were, send his wife and young daughter to his wife's parents, and leave England. He had no assurance that he would ever see his family again.

America or the colonies? John Goodwin chose America and embarked for New Orleans on a sailing vessel. He was sixty-one days on a midwinter ocean in a coffin ship carrying a passenger list many times too large for its accommodations.

From New Orleans, the emigrant worked his way up the Mississippi as a roustabout on river steamers, stopping at St. Louis and finally Cincinnati.

The History of the Upper Ohio Valley, a volume published in 1891, tells of the next and final deciding step in his selection of a future home: "His next stopping place was Cincinnati, whither he went for the purpose of securing employment, but finding a scarcity of work, he started to Pittsburgh. While en route to the latter place, he learned there was a small pottery at East Liverpool, Ohio, so he concluded to make this town his objective point." He arrived in this river hamlet May 25, 1842.

Mr. Goodwin secured his first job in the factory of James Bennett, the man who built the initial pottery in the town.[1] Later that same summer, he formed a partnership with Thomas Croxall and Edward Tunnecliff to make their own pottery. They had less than one hundred dollars and no equipment.

Benjamin Harker,[2] who two years before had started a pottery on the Ohio River road east of the village, leased them his shop on equal shares. The plant consisted of a one-room cabin, a sliphouse, and an outside kiln. The blunger used in mixing the slip had been made by Isaac Knowles, the town carpenter.[3] All of the equipment was extremely primitive, and the ware produced was of inferior quality.

After several months of trying to make creditable ware, John Goodwin became impatient. He was certain that something was wrong with either the body or the firing and determined to investigate the cause. Finally, the Englishman decided that the ware was not being fired at the proper temperature.

Accordingly, one morning, he appeared in the kiln shed and announced to his partners that he was going to fire that particular kiln of ware.

Thomas Croxall, who had charge of the firing, was astonished almost beyond expression. "Ye 'ave na call to say I canna fire th' oven," he protested angrily. "Man an' lad I've fired ovens in th' ould countree for many a year."

Mr. Goodwin reiterated doggedly that he was going to fire the oven. His partner's indignation did not alter his determination. The potter was certain the ware was not being fired properly and he intended to correct this fault.

The first step was to tear out the fire pots and make them larger. Then he set about prewarming the kiln before loading it. When it had reached what he considered the proper temperature, he carried the filled saggers unassisted to the kiln, placed them, closed the opening with brick, and set about firing the kiln. The wood was piled in until the pots were crammed. The heat began to roll and the black smoke poured from the stack, but Mr. Goodwin did not relinquish his vigilance.

Mr. Croxall watched the proceeding with anxious eyes. Finally, he could no longer control his alarm. "John," he made one last protest. "Th' oven is too 'ot. The ware will be flown."

"Nay," retorted the dirty, perspiration-streaked fireman. "I wunna flown, dunt, crack, or make it crooked. The ware hasna been fired aright."

When the forty-eight hours allotted to the firing had elapsed, and the kiln had cooled for ten hours, the ware was ready to be drawn. Mr. Goodwin tore away the hot brick of the opening. The kiln was very warm, but it was possible to enter. He settled his padded cap more firmly on his head and went through the opening. Outside Thomas Croxall, Edward Tunnecliff, Benjamin Harker, and his two sons, George and Benjamin, Jr., waited. No sound came from the depths of the round-bellied kiln. Tom Croxall became impatient and ran up the short flight of steps to the opening.

"Comen out, John!" he called. "Whate're is th' matter?" he asked as he lowered his head and entered the kiln. "By Gonny!" His voice dropped to a shocked whisper. "Wun ye look at th' ware!"

The saggers and ware were fused into one solid, unmarketable lump and would have to be pried from the sides of the kiln with a crowbar.

It was a sad experience for John Goodwin—one that he never forgot. The severe financial loss, as represented by the worthless ware, did not, however, daunt the man. He used it as a steppingstone to greater achievements. In the winter of 1842–1843, he became dissatisfied with the arrangements at the Harker pottery and began manufacturing under his own name.

All the money he possessed was eighty dollars. With this small capital, he rented a vacant warehouse and remodeled it to suit the needs of a pottery, doing all the work unassisted. It was a crude beginning, but it was the foundation for one of America's leading potteries of the nineteenth century.

The young potter labored long hours and lived frugally, and by the spring of 1843 had saved enough money to send for his wife and daughter. The young Englishwoman was not permitted to stay in America long, however, for she died the year following her arrival in the New World.

His wife's death, although a stunning blow to the potter, did not retard his ambition to become firmly established as a manufacturer. During the ensuing months, Mr. Goodwin astonished his fellow townsmen with his daring and initiative.

In 1845, he enlarged his production to include the mak-

[1] For an account of the Bennett Pottery, see *Bull. Amer. Ceram. Soc.*, **16** [1] 27–28, 30 (1937).

[2] The Harker Pottery Company celebrated its centennial anniversary in 1940. At this time, a history of the Pottery was published in *Bull. Amer. Ceram. Soc.*, **20** [1] 25–27 (1941).

[3] Mr. Knowles later founded the Knowles, Taylor & Knowles Company and introduced machinery into ceramics in this country. For the story of this Pottery, see *Bull. Amer. Ceram. Soc.*, **21** [8] 152–57 (1942).

ing of Rockingham doorknobs, and he became the first potter in East Liverpool to make these necessary home accessories. These knobs were sold in the Pittsburgh market at four dollars a hundred, delivered.

Mr. Goodwin did not make his doorknobs by the same process used later by the Brunts.[4] Slip was mixed by the ancient "horse ring" method in a large vat sunk in the ground. Round and round the horse plodded in the vat until the clay and water were properly blunged. Then the slip was dipped from the huge tub into haircloth lawns through which it passed into containers known as "slip kilns." If the weather was sunny and the air hot, these kilns were left to dry naturally; otherwise, fires were built beneath them. The clay was stirred constantly to keep it suspended until all the water had evaporated.

In the 1840's, the filter press and pug mill were unknown. John Goodwin took care of his clay as he had been taught in England. He wedged it by hand. The soft masses were pounded, cut, rolled, and pulled until every bubble had disappeared. It was then shaped into rolls. The clay was "thrown" into long "stalks," placed on boards, dried, turned, and "pinched" into the desired style.

Historians have accepted the belief that William Bloor was the first man to produce whiteware in East Liverpool.[5] From the records of John Goodwin, kept intact for many years by his son, James, and later by his grandson, the late Charles F. Goodwin, it has been definitely proved that John Goodwin made whiteware as early as 1846. According to Charles Goodwin, the entire story was set down in these record books by his grandfather at the time the whiteware was produced. He made several pieces of the ware, among them a custard cup which has been preserved until the present time.

The ware was made from samples of china clay mined near Hollidaysburg, Pennsylvania, and from a specimen of clay from Missouri. The two clays had been sent to him for trial.

The potter mixed the widely separated clays, using no other ingredients. The combination produced a type of ware which took the uncertain glaze of that period perfectly. To the surprised workman, the ware closely resembled the queen's ware of his native land. Mr. Goodwin was so impressed by the beauty of the pottery he had created that he recorded the process step by step.

The *East Liverpool Tribune* of October 24, 1891, printed the following story: "While digging the foundation for a new building at the pottery of S. & W. Baggott, workmen unearthed a relic of rare interest in pioneer pottery in the Ohio Valley. It was a small custard cup, made without handles, but with a foot and of handsome shape. It was a beautiful cream color, and the brilliancy of the glaze at once attracted the attention of the workmen. On the bottom of the cup, written in clay under the glaze in a bold hand, were the words 'J. Goodwin, 1846.' The cup was taken to the Goodwin brothers, who recognized their father's handwriting.

"Mr. James Goodwin consulted his father's memorandum books of 1846 and found the cup recorded. The clay used was a combination of clay sent to him from a mine near Hollidaysburg, Pennsylvania, and from Missouri.

"In those days, there were no such things as flint and feldspar. The remarkable thing is that the union of two clays and nothing else added to the body should produce such ware and take the glaze. The piece has stood the crucial test. For thirty-four years, since the fire of 1857 when the factory was badly damaged, this piece has lain buried in debris. The glaze has no sign of cracking or crazing.

"John Goodwin was then the first man to produce white- or cream-colored ware in East Liverpool. Other pieces of the same ware have been found, but the cup was the only whole piece. The Goodwin brothers have memoranda of these early tests, and Mr. Goodwin left his sons written testimony of his experiments."

The pioneer potter did not manufacture whiteware for sale. His production of it was brought about by the lucky fusion of two freak clays. He did, however, make whiteware almost at the beginning of the pottery industry in East Liverpool. Although this fact does not minimize the importance of William Bloor's contribution to American pottery making, it should establish some kind of record and obtain another bit of recognition for this famous potter of long ago.

Among the trials of the early potters was the problem of proper glazes. They could not be made according to formulas of the English potters for the simple reason that the necessary materials were not commonly used in America. The first ceramists in East Liverpool utilized the ingredients at hand, and the results were, to be conservative, quite remarkable.

John Goodwin was a master glazemaker. His reaction to the glaze used by his competitors was one of disgust mingled with impatience. The question baffled him, and no solution seemed possible because the proper materials were not available.

"I wunna turn out crockery with bad glaze," he declared emphatically to a friend one summer afternoon. "And yet, I hardly know what to do about the matter."

"Come fishing with me," suggested his friend. "I always think better when I'm fishing."

John Goodwin laughed derisively. "I canna be making glaze out fishing." He took the man's arm and led him to the kiln-shed door. "See that pile of shard over yon? That is made from Pennsylvania and Missouri clays, and it turns out to be whiteware. Now, I've been thinking if I could grind up that shard and mix it wi' sand mebbe it 'as some 'idden properties. What think ye?"

"I wouldn't be able to help you," confessed his friend, who was a prosperous farmer. "But there's sand along the river. Why not try it?"

A few weeks later, the two friends met in the village general store. "Well, John," the farmer inquired, "did the sand suit your purpose? I hear you've been doing a sizable amount of digging along the river shore. There's some people who think you're slightly batty."

"I will be soon, if I canna get a glaze to suit me," Mr. Goodwin replied wearily. "The sand was too dark and didna work. I must have white sand. And where can I be gettin' white sand about here?"

[4] The part the Brunts played in the East Liverpool pottery inductry is detailed in the story of William Bloor, see following footnote.

[5] See "William H. Bloor," *Bull. Amer. Ceram. Soc.*, **16** [1] 25–31 (1937); the account of the Bennett Pottery previously referred to is also included in the Bloor story.

"Better come fishing," invited the farmer easily. "Out on Little Beaver Creek there's a good supply of white sand."

The suggestion was made so casually that Mr. Goodwin was about to refuse it impatiently when the import of the man's statement filtered through his harassed brain.

"Comen along," he shouted. "Let's go fishin'!"

The white sand along Little Beaver Creek proved to be the grade Mr. Goodwin needed. He mixed it carefully with ground white shard and produced a limited amount of exceptionally fine glaze. The pieces dipped in it were excellent and sold at prices heretofore unknown among the local potters. He could leave no written proportions of that early formula, however, for the hidden properties of the Pennsylvania and Missouri clays remained a secret he could not probe.

In 1846, the pottery industry of East Liverpool was very small. There were five potteries, and thirty men, beside the employers, worked in the shops. Union and wage agreements were unknown, yet the first strike in the local potteries occurred that year, and the cause was "lack of uniform wages."

One evening in the autumn of 1846, a workman from the John Goodwin pottery entered Josiah Thompson's general store. A group of men were gathered about the glowing fireplace. It was Saturday and payday in the shops. The weekly store orders, given in lieu of money, were filled and waiting in baskets to be taken home.

"It won't take long to fill your order," Thompson told the newcomer. "John Goodwin is the only boss who pays this way."

"Aye," replied the Englishman. "John 'as been in th' ould countree and knows what it means to do without cash."

"We get paid in money, too," interrupted a tall potter, whose sallow complexion and quick cough was indicative of his occupation.

"That!" The first man spat contemptuously. "A shilling maybe, but na a fat sum alike we get. John pays us 'alf an' 'alf."

A hush fell over the group. The men shifted their feet uneasily and looked at each other questioningly.

"'Alf an' 'alf what?" asked a man from the far edge of the group.

"'Alf money, 'alf victuals," elucidated the Goodwin potter briefly. "Ye dinna get more than a few pence an' the rest in store orders. On pay nights, John gives us 'alf our wages in cash, th' other 'alf in store orders."

The seed of discontent was sown and began to bear fruit on Monday when the men returned to their benches. The rumbles of insurrection spread throughout the shops like wildfire. Wednesday afternoon, the three workmen on the pay roll of the Ball and Morris pottery confronted Thomas Ball with the ultimatum that he pay them "'alf an' "alf" or they would refuse to work.

The scene was repeated in other potteries during the next few days. The man at the bench was beginning to assert the freedom he had come so far to find. The manufacturers could not cope with the problem, and an indignation meeting was held in John Goodwin's pottery.

"'Tis a lot o' foolishness," fumed James Salt. "Must ye be different from the rest o' us, John Goodwin?"

John Goodwin tilted his chair on its back legs and became interested in a small knife he held in his work-hardened hand.

"This time ten years ago," he responded slowly, "I was afraid to call my name my own. I worked sixteen hours a day and had no money for my 'ire, only orders on the tommy shops in the ould countree. Sumtimes I 'ad no store orders if the buttie at the James Edwards potbank saw fit to take out for breakage. I know what it means not to 'ave enough to eat or to wear. I'm treatin' my men alike I'd want them to treat me if I was aworkin' for them. You men," he raised his head and peered at them sternly, "are na so far from England's Potter's Quarters to be forgettin' what ye 'ad to put up with over there!"

The fearless words of the English potter brought an exchange of shame-faced glances between his visitors. Benjamin Harker cleared his throat loudly.

"Ye are right, John," he conceded hastily. "We almost forgot that we are na pot-masters in the ould countree, but we are in America now, free men. We've na right to put on our men what we left behind in England. I'll pay my men 'alf an' 'alf."

The strike ended almost before it began, and the men received their weekly wages the following Saturday night "'alf an' 'alf!"

Labor troubles, poor materials, and lack of markets were only a few of the difficulties besetting the early potters. Among the legion of problems they had to overcome was the "wildcat" money flooding the country in the year preceding the Civil War.

The only stable pieces of money were the half-cent, cent, nickel, dime, quarter, half-dollar, and dollar. All paper currency was issued by banks in various large cities. A five-dollar note issued from a Wheeling bank would have a value of three dollars when redeemed in Pittsburgh. Thus the term "wildcat" money came into common usage.

As a result of the uncertain condition of paper currency, the readers of pottery history have a choice story to chuckle over—the story of John Goodwin and Joseph Cartwright. The latter operated a storeboat between East Liverpool and New Orleans.

Mr. Cartwright, in the spring of 1848, purchased ware from John Goodwin to stock his boat for his annual trip down the river. The only financial arrangement made between the two was the profit Mr. Cartwright was to make on the sale of the goods. A day or so after his departure from town, John Goodwin realized that he had not specified what kind of money the merchant was to use in paying him for the dishes. He knew that unless he did something immediately, he stood in a fair way of losing all his profits on the transaction. Accordingly, he boarded the next down-river boat and sighted the storeboat tied up at a wharf near Wheeling, West Virginia.

Joseph Cartwright was surprised to see his visitor. "Good evening to ye, John," he rose from his seat on the narrow deck and held out his hand in greeting. "What brings ye here?"

"'Tis this," replied Mr. Goodwin without preliminaries. "We made no plans for payment of the crocks. Ye must not be payin' me in truck or bad money."

Mr. Cartwright was justifiably angry, and the conversation between the two men became spirited. Mr. Goodwin,

however, left the store owner with the assurance that he would be paid in good money.

One evening late in the summer of the same year, Joseph Cartwright returned to East Liverpool on the steamboat *Winchester*. As the boat docked, he called to a small lad standing on the beach and instructed him to get John Goodwin. The latter was to bring a wheelbarrow with him.

A few minutes later, the potter, pushing a wheelbarrow, came hustling down the narrow path leading to the river's edge.

"Gud evening to ye, Joe," he greeted the other man breathlessly. "Just what do ye want with this barrow?"

"Your good money is here on deck. You best have help in gettin' it," replied Mr. Cartwright nonchalantly.

John Goodwin hurried aboard. It was as the merchant had said. He needed help. A gunny sack filled with clinking coins lay on the deck. The potter, with the aid of one of the deck hands, carried the bag down the gangplank and placed it in the wheelbarrow. He began his laborious trip to the pottery, followed by a number of laughing and curious townfolks.

When Mr. Goodwin arrived at his shop, the contents of the sack were dumped on the warehouse floor. It was good money as he had requested, but it was half-pennies and one-cent pieces. It took the greater part of three days to separate and count the financial return from the business deal he had contracted with Joseph Cartwright.

In the East Liverpool Historical Society collection is a handbill, printed in 1850, telling of the various pieces of merchandise produced by the Goodwin pottery. The ware was extremely diversified and speaks highly of the business acumen and ability of the man who had started his pottery eight years before with the meager capital of eighty dollars.

LIST OF MERCHANDISE PRODUCED BY THE JOHN GOODWIN POTTERY, 1850

YELLOW WARE

Chambers	Flowerpots
Pitchers	Twelve-in. dishes
Bowls	Twelve-in. nappies
Milk pans	Pie plates

ROCKINGHAM

Pressed pitchers	Turned pitchers	Butter tubs
Flowerpots	Honey bowls	Turned washbowls
Turned ewers	Pressed ewers	Coffeepots
Pressed teapots	Pressed sugars	Pressed creamers
Bedpans	Spittoons	Sauce dishes
	Salad dishes	

Some of the records of those early days tell that John Goodwin "made yellow ware and Rockingham so thick and heavy that a breakfast cup could be used in lieu of a carpenter's hammer."

In 1853, Mr. Goodwin sold his pottery to Samuel and William Baggott, eccentric Staffordshire potters, and for the next few years dropped out of the pottery business entirely. He sold real estate, entered politics, and tried his hand at various occupations. But not for long, for the art of making dishes was in his blood, and he could not remain away from his potter's wheel for any length of time.

An old history of Columbiana County, Ohio, relates the following concerning his activities during the next few years: "John Goodwin, Sr., who had operated in real estate for several years after selling his original plant to the Baggotts in 1853, re-entered the pottery business in 1863 when he built a plant on the southeast corner of Broadway and Sixth Street in East Liverpool. The factory was composed of two kilns and was one of the first plants in East Liverpool to have been designed by an architect. In 1865, he abruptly withdrew from the concern and remained out of pottery making for nearly five years."

The Centennial edition of the *East Liverpool Review*, printed in 1934, resumes the story of John Goodwin's ceramic efforts: "In 1870, John Goodwin went to Trenton, New Jersey, where he was interested in the Trenton Pottery Company for two years." Behind that bald statement of facts lies a story of a father's ambition for his sons and his hope that they would follow him as potters. He had three children by a second marriage, James, Henry, and George. As the boys neared manhood, he decided to launch them in the career of pottery manufacturing. The Trenton Pottery Company was comprised of James Taylor and Henry Speeler, former East Liverpool potters, and John Goodwin. The new firm was organized as Taylor, Goodwin & Co.

The American potters were suffering keenly from the unfair treatment they were receiving from foreign trade propagandists, and the factories were operating at partial capacity production. Buying of American pottery dropped away to almost nothing, and it seemed for a time as though American potteries would soon be only a memory. Then, an enterprising domestic manufacturer conceived the idea of marking his ware with a foreign trademark and offering it as English or French merchandise. The result was amazing, sales gained a new tempo, and the public was hoodwinked into believing the new patterns were of foreign creation. The trademark "T-G & Co." found on the bottom of John Goodwin's Trenton-made ware was interpreted as belonging to a then famous English ceramic company which had the same initials. When John Goodwin discovered the hoax and found that their spurt of prosperity was due to misrepresentation, he sold his share of the pottery to his partners and returned to East Liverpool in 1872.

The *Review* account picks up the story again: "In 1872, he returned to East Liverpool and purchased the Broadway pottery from James Foster and Timothy Rigby. He acquired additional land and engaged in the manufacture of whiteware, which was then securing its start in East Liverpool. John Goodwin died in 1875, leaving the business to his sons, James, George, and Henry Goodwin, who formed the Goodwin Brothers pottery to manufacture white granite."

The factory John Goodwin purchased was equipped to make Rockingham and yellow ware. When the pioneer's death occurred in 1875, plans were afoot to make the expensive change to whiteware production. The demise of their father placed the sons in a precarious position. They knew additional money was necessary before they could complete the projected plans, and the question of finance became serious.

"James, I am certain Father left more money than we have accounted for in the estate," George Goodwin told his brother wearily one afternoon as the two left their

attorney's office. "I have literally turned our house inside out, and I can find no trace of it."

"We may have misunderstood Father about the bonds," his older brother replied thoughtfully. "Perhaps he used his surplus when we purchased the plant. We will have to do the best we can, but a few extra thousand dollars right now would mean the difference between our operation as whiteware potters or our staying in the rut we are in now."

James H. Goodwin, the oldest son of John and Esther Smith Goodwin, who was recognized as one of the pottery leaders of his generation. His death occurred on election day in November, 1896.

"I'm not going to give up," George answered doggedly. "I'm positive Father left bonds."

For several weeks, the brothers continued a diligent search for the missing bonds. Everyone knew of the aged potter's habit of hiding money in unexpected places. Carpets were lifted and presses and bureau drawers were inspected closely, but the bonds were not to be found. The two older Goodwin brothers were ready to give up the quest. They were convinced that the bonds were lost or their father had cashed them three years before.

One day, a few months after his father's death, Henry, the youngest son, called at his brother James' home for a romp with his four-year-old nephew, John. Before long, the two were playing boisterously on the floor.

"Watch out, lad," Henry cautioned John. "We almost knocked Grandpa's chair galley-west."

He pushed the horsehair-upholstered rocker, which had been his father's favorite chair, out of the way. The child, seeing his opportunity, leaped on the back of his youthful uncle, and the two rolled against the chair, which crashed over on one side. They settled back, and Henry surveyed the chair with astonishment. The burlap webbing had been torn loose from the bottom, and a long packet of papers lay in plain view. Henry tore away the outside cover and there were the long-lost bonds—$5000 worth. The brothers were able to make the needed improvements in their pottery and begin the production of white granite-ware.

The era of machinery used in pottery making was in its infancy during the early years of the Goodwin Brothers pottery. The pulldown jigger and filter press were the first pieces of machinery used in making pottery, and they were operating in only a few of the plants. Wedging, slip kilns, blindfolded horses treading about slip vats, throwing, turning, and pressing were utilized in a large majority of the plants, particularly the trade of wedging. Every sliphouse had bricked-up, plaster of Paris-covered wedging blocks, and the wedgers were men of great strength. Day after day, the wedger would lift heavy chunks of moist clay high above his head and bring them to his block with resounding thuds. His skillful fingers would knead and pummel the mass until all of the air bubbles were removed. The introduction of a machine to replace this ancient trade came as a complete surprise to the potters and was brought about by James Goodwin.

George Goodwin, the second son of John and Esther Smith Goodwin, whose death occurred a decade ago. This picture was taken in 1914.

The story of the first pug mill comes from the memory of the late Charles F. Goodwin, a son of the man who was responsible for its induction.

"In 1880," Mr. Goodwin related, "my father was vacationing in Wisconsin and visited a lumber factory where

his attention was drawn to an ingenious machine known as a wood-pulp mill. As Father watched the uniform operation of the wood being fed into the hopper and emerging as pulp from the bottom of the mill, a fantastic idea flashed into his mind. Could clay be fed into a similar machine? Would the knives be sharp enough to find all of the air bubbles and would the pressure be sufficient to press the clay through the opening at the foot of the machine? He became so obsessed with the idea that before he left Wisconsin he purchased one of the machines and ordered it sent to our factory.

"A week or so after his return, the machine was delivered. It was an unwieldy contraption, and the wedgers in the sliphouse watched its installation with amused contempt. The mill was an upright type, standing six feet above the floor. A series of shafts, knives, and intermeshing wheels was operated by steam from the engine room. The mill was set solidly on a stone foundation. The opening at the bottom of the large cask stood 18 inches from the floor. Everything was in readiness for the experiment.

"The workman hauled the leaves of clay to position by the large mill. The lever was thrown, and the wheels, shafts, and knives sprang into action. The pugger (as he was known later) folded the first leaf of clay and dropped it into the mill. The crowd was breathless. There was no sound in the sliphouse except the throbbing of the ex-wood-pulp machine. Other leaves followed. Then from the hole at the bottom of the mill emerged a cylindrical stream of smooth clay. It moved into a trough and was sliced into long rolls for the jiggermen."

The pug mill became an accepted necessity to the potters, but it was protested for many years by the wedgers. For a long time, if a jiggerman wished to have his clay pugged instead of wedged, he had to pay the wedger for the accommodation. The pattern taken from the wood-pulp machine was used in the manufacturing of pug mills for many years. After a time, improvements were added, but the elementary principles remain the same today as they were in the machine James Goodwin brought from Wisconsin more than sixty years ago.

The *Review* Centennial edition relates that "the Goodwin Brothers Pottery company was incorporated in 1893." The pottery was growing by leaps and bounds. Reduced tariff, walkouts, and strikes were accepted as part of a pottery manufacturer's life, and the pottery was well on the way to becoming one of the most progressive plants in the industry. They brought out a new shape in dinnerware, quite an innovation in the days when practically every pottery made cableware year in and year out. The dinner set was named "Fawcett" after Thomas Fawcett, one of their ancestors and the founder of the town. Its introduction caused quite a furor among the potters. Every indication pointed to success for the Goodwin Brothers pottery when, in 1896, tragedy struck the firm.

On election day of that year, James Goodwin, who was the motivating power of the organization, was found dead from a heart attack. He had worked unceasingly to bring about the presidential election of his friend, William McKinley. His untimely death closed a successful career as a pottery manufacturer and ceramic authority.

The Centennial edition tells simply and graphically of the closing days of the Goodwin pottery. "James Goodwin's place in the business was taken by his two sons, John S. Goodwin and Charles F. Goodwin, who continued in the firm established by their grandfather until the death of John in 1909 and the retirement of his two uncles. The Company discontinued operation in 1911."

Even though the Goodwin family was no longer identified with the industry as active manufacturers, Charles Goodwin remained as an important executive of the industry from 1912, when he was elected secretary-treasurer of the United States Potters Association, until his death in December, 1941.[6]

Charles Fawcett Goodwin

There are a number of descendants of John and Esther Goodwin living in East Liverpool and in scattered parts of America. Their occupations have taken them far afield from the art of making pottery. Most of them are successful in their chosen trades, and, although one or two members of the Goodwin family are employed in pottery making, none are manufacturers. The death, therefore, of Charles Fawcett Goodwin, which occurred while he was attending the annual convention of the United States Potters Association in Cleveland, Ohio, marked the end of the Goodwin family as pottery manufacturers and executives in ceramic endeavors, after a continuous span of ninety-nine years of service in that capacity.

797 Ohio Avenue
East Liverpool, Ohio

[6] For a biographical sketch of Mr. Goodwin, see *Bull. Amer. Ceram. Soc.*, **21** [1] 5 (1942).

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In 1941, this Society spent $1.60 in your interest for each $1.00 paid in as Personal and Corporation membership dues.

SYMPOSIUM ON "TESTING AND CLASSIFICATION OF BALL CLAYS"*

RALSTON RUSSELL, JR., *Presiding Chairman*

INTRODUCTION

CHAIRMAN RUSSELL: John Koenig of the Hall China Company has acted as chairman of the Research Committee during the past year. After his appointment, we discussed the Committee functions, and tentatively agreed that the Research Committee should extend its activities. At a later date, we met rather informally with Professor Watts and Karl Schwartzwalder, at which time this subject of the activities of the Research Committee was discussed. It was generally agreed that the Research Committee could very well perform an added function to the Division and to The Society.

The question then arose as to how the Committee could perform this function. It was proposed that a cooperative research should be sponsored within the Division, the nature of this research to be such that the various members would have an opportunity to contribute to the solution.

It was then necessary to decide what specific problem to investigate and the type of research to be conducted. Several possibilities were considered, but the only one which seemed to have a general scope of interest to all of our members was the subject of ball clays.

Practically every whiteware manufacturer uses ball clay in one form or another, but the whole subject of ball-clay properties and uses needs clarification. Even though all manufacturers use ball clays, very few actually know the relative merits of different ball clays or can explain the reasons for their many peculiar characteristics. Many theories have been proposed to explain ball-clay properties and to classify them for certain uses, but the whole situation is rather confused at the present time.

In order to reach a final decision, it was decided that the best plan would be to obtain the personal reactions of a number of men in the industry. As a result, about twenty representatives of the whiteware industry were contacted, seventeen replies were received, and in practically every case the general feeling was expressed that the study of ball clays was worth while and that all would be willing to cooperate. Consequently, a final decision was made that the Research Committee would sponsor a cooperative investigation of ball clays.

The objectives of this research should first be outlined. The primary objective is to encourage a cooperative effort within the Division itself in order to consolidate the interests of the Division in all of its activities.

The objectives of the ball-clay research as such are twofold, but there are also several minor objectives. The first objective is a study of the fundamental properties of ball clays as related to their common physical properties with an attempt to correlate these two classes of properties to obtain a better understanding in the selection, use, and testing of ball clays. The second objective is an attempt to understand the fundamental nature of ball clays and to determine why they have such characteristic properties and behaviors.

Among the minor objectives is the necessity of developing fairly standardized methods of testing, and this happens to be in line with the current program of the Standards Committee of this Society.

Another secondary objective, and one which has been mistaken by some of the ball-clay producers for the major objective, is a classification of the uses and properties of commercial ball clays. It would be rather difficult to carry on this research to finality without some type of classification of the ball clays themselves, although such a classification may not be entirely desirable or even feasible.

Some persons have expressed the opinion that in sponsoring this investigation we were accepting a responsibility which does not belong to The Society. There is a possibility of detrimental effort, but this is remote. No producer could complain if we were to determine the best uses for his particular clays and to classify them so that the manufacturers would be able to use the clays in the best manner possible. For example, certain ball clays at the present time are being used in applications where others could probably be substituted advantageously. As a result of better understanding, replacements may be effected. Those ball clays, however, which are released in most cases will find other applications in which they offer advantages, and a better usage all around will be the net result.

It is our hope in this whole effort that we shall have the cooperation of the producers as well as of the consumers. The members of the Materials and Equipment Division have been invited to attend this meeting in joint session, and we are happy to have them contribute to this Symposium.

The objectives have been set forth, and we return now to the development of our plans. Following the final subject selection, a questionnaire was sent to every member of the White Wares Division to solicit cooperation. The first questions asked were, "What properties of ball clays are of interest?" and "What tests are considered most important for ball clays?" This resulted in a list of properties and tests which the consumers consider to be of most importance. These will be discussed in detail.

The next question was, "What extent of cooperation could be expected from the members of the Division?" Forty manufacturers exhibited a willing spirit of cooperation by offering to help in the testing and development program. Such cooperation is of course vitally essential.

Every university and research organization in the country which is interested in ceramic problems has been contacted and twenty of these agreed to cooperate. The situation at the present time looks favorable. The decision as to our future activities will depend on this meeting and on the interest shown here, because committees cannot do all of the work.

John Koenig, who has been developing this program with me, has been called into the Service, so I shall be forced to carry on without his able assistance.

I would like to present A. S. Watts, who has guided us in this undertaking and has helped a great deal in consolidating our efforts.

A. S. WATTS: My purpose in promoting this Symposium was to bring into the open a lot of material which you have heard repeatedly, and you have all participated in the discussion forum. There is no occasion, as Dr. Russell has said, for anybody to feel that this is the preliminary round "to any kind of a dog fight"; it is a round-table discussion of what we know, what we would like to know, or what we need in connection with ball-clay information. Everyone should recognize that all that is said here is the personal opinion of the speaker and has no motive other than to try, either through his own statement or through solicited statements, to clarify this ball-clay situation.

* Presented at the Forty-Fourth Annual Meeting, The American Ceramic Society, Cincinnati, Ohio, April 22, 1942 (Joint Session of White Wares and Materials and Equipment Divisions). Entire discussion received July 1, 1942.

CLASSIFICATION OF BALL CLAYS*

By Arthur S. Watts

I. Can Ball Clays Be Classified?

Many competent persons with long experience contend that each ball clay is an individual and that, beyond a general grouping based on a few characteristics in the raw state or on a few properties disclosed on firing, a classification would have little value.

The same attitude prevailed regarding feldspars when Ladoo and his associates[1] undertook their task, but a great advance in the intelligent choice of a feldspar for a specific purpose resulted from their work.

A similar service can be accomplished with ball clays, although the problems are more complex and more difficult.

II. What Would Constitute the Basis of Such a Classification?

Ball clays are employed because of (*a*) their plasticity (this property should receive first place in any classification), (*b*) dry strength, (*c*) drying shrinkage, (*d*) impurities, and (*e*) response to electrolytes.

In the fired state, the important properties are (*a*) temperatures of vitrification, (*b*) rate of vitrification, (*c*) fired density, (*d*) fired strength, (*e*) firing shrinkage, and (*f*) fired color over the vitrification range.

III. How Can a Group of Ball Clays Which Are So Dissimilar in Properties Be Classified?

Each property could be listed in approximately five grades from high to low, i.e., plasticity 3, dry strength 2, drying shrinkage 1, impurities 3, response to electrolytes 4, temperature of vitrification 2, and rate of vitrification 3.

The prospective user would thus be able to note quickly the properties which are important and choose the clays of interest to him.

It is not proposed that actual tests be conducted by The American Ceramic Society and that clays be evaluated, but merely that a mechanism be provided so that all ball clays can be reported according to a standard set of units.

A supplemental classification could and should be set up by each branch of the ceramic industry which would indicate the range of tolerance within which each property would be acceptable and the order of importance of the various properties.

This plan of classification is presented merely to induce thought and criticism with the idea that in the end some practical system will be agreed upon.

IV. Development of Test Methods

The real problem is the development of test methods, which must be studied and agreed on before any classification can be developed.

The tests now employed and the problems involved are as follows:

(*A*) *Water of Plasticity:* The degree of wetness of the clay or mixture is now a matter of personal judgment, and few people or plants agree on the state of wetness necessary for test purposes. As any variation in this respect affects practically all properties, some standard system for determining the amount of water to be used is essential.

(*B*) *Type of Water Used:* A wide variation in properties results from the use of a hard water versus a soft or a distilled water. Some scheme of adjusting or standardizing the water used is desirable.

(*C*) *Bonding Strength vs. Plastic Flow:* These tests are needed more than any other test. The plate adherence test described in a Department of Commerce Bulletin[2] is good for bonding strength tests if the water of plasticity is correctly chosen; otherwise it is of but little value. The details of the test need careful study. The test for plastic flow (or greasiness) has never been developed, although every person who molds a plastic body recognizes the importance of this property.

This problem should be approached as a long-time study. Every item should be thoroughly analyzed and discussed before the formulation of a classification system and standard tests is attempted.

Department of Ceramic Engineering
Ohio State University
Columbus, Ohio

* Received April 22, 1942.

[1] R. B. Ladoo, "Conditions in the Feldspar Industry," *U. S. Bur. Mines Rept. Investigations*, No. 2311, 10 pp. (1922).

[2] Technologic Paper No. 227, pp. 156–57.

Discussion

A. S. Watts: In a recent test, only bars were made, and there was no mention of the state of wetness of the material used for the bars. All of us who have had practical experience realize that if the amount of water in a plastic mixture is changed even by 1 or 2%, practically every property value in the test will be changed, and more information must be obtained, particularly for dry pressing, plastic molding, and possibly for casting as a preliminary test of the wetness or the water of plasticity which will be employed.

L. E. Thiess: Does this imply that the present standards are not good enough or in most cases are obsolete for making tests?

A. S. Watts: We do not have sufficiently definite standards established to meet the actual needs of today. Some of them may serve, but more are needed. We have an excellent opportunity to ascertain the value of test methods. If ten students are given the same information and the same clay, they may get a variation of ±10 or 20%; this is conclusive evidence that the test procedure needs some clarification. Maybe we cannot provide such clarification, but we can try to improve on these tests.

I. E. Sproat: Would it be possible to start with dry clays and, by using high pressure, leave all of the water out entirely?

A. S. Watts: I doubt whether such procedure would give the necessary information. The man who proposes to use a ball clay as a casting ingredient probably would not get the information he needs. He might get physical values, but I question whether our group is interested in ultrascientific physical values. Perhaps by assembling or listing them with our practical experience, they may be of value.

BALL CLAY IN ELECTRICAL PORCELAIN BODIES*

By L. E. Thiess

I. Description and Composition of Ball Clay

Ball clay is an important and, as a rule, the least controllable ingredient of a whiteware body. Its function is to supply plasticity and dry strength. Acting as a flux at high temperatures, it also gives great toughness to the fired product.

In casting bodies, ball clays, especially the dark clays (i.e., those clays which contain a large amount of organic matter and organic electrolytes), produce fluidity in the casting slip.

Ball clays do not differ greatly in composition from the kaolins or china clays, except that they contain such impurities as iron, titanium, organic matter, lime, magnesia, and alkalis. The essential clay mineral in ball clay is kaolinite. The results of the thermal analysis of two highly plastic and fairly low-sintering ball clays (an English and a Mississippi ball clay) are shown in Fig. 1. These

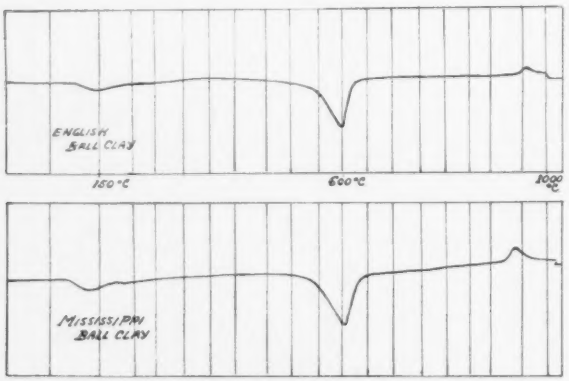

Fig. 1.—Thermal analysis of English and Mississippi ball clays.

tests were made on an apparatus designed by Norton.[1] Both curves show the characteristic exothermic reaction near 980 °C. and a definite peak at the endothermic reaction at 610 °C. Another endothermic effect at the lower end of the temperature scale (about 150 °C.) indicates the presence of montmorillonite. Each ball clay is fine grained and has a high bonding strength.

II. Use of Ball Clay in Porcelain Bodies

Electrical porcelain is made by (1) the plastic or extrusion process, (2) the dry process, and (3) the casting process. The composition of the bodies used for each of these manufacturing methods differs, especially in the ball-clay content. Certain ball clays are suitable for only one of these processes. The type of ball clay required for each of the following bodies is therefore discussed.

(A) Plastic or Extruded Bodies

The amount of ball clay varies from 25 to 30% and, as a rule, a blend of clays rather than a single ball clay is used. Cylinders for high-tension insulators, which vary in diameter from 2 to 15 in., are extruded or shaped almost entirely on vacuum pug mills. The ball clays used in such plastic bodies must be fine grained, highly plastic, and tough. Inasmuch as ball clay also serves as a lubricant during the plastic flow in these extrusion machines, such clays known as "fat plastic" or "greasy" are the most desirable. The ball clays must also be clean, i.e., they must be low in coarse carbonaceous matter so as to avoid black cores in heavy cross sections; light, clean ball clays, therefore, are preferred. Watkin[2] shows that a large amount of ball clay in such highly vitrified bodies lowers the electrical puncture value because the large amount of organic matter burns out during firing and leaves small pockets or pores in the fired structure.

The best ball clays for extrusion are low-sintering clays which vitrify completely at or below cone 9. These clays give a longer firing range to the body in which they are used. Some of the highly plastic and fine-grained English ball clays vitrify below cone 8; others, however, develop a bloated or vesicular structure above cone 10 owing to overfiring. Few of the domestic ball clays vitrify completely below cone 10.

(B) Dry-Process Bodies

The amount of ball clay in dry-process bodies varies from 10 to 20%. The ball clay must be highly plastic, have good dry strength, and fire light in color. The drying and firing shrinkages must be considered. Air-floated clays for dry-mixed bodies must contain little dirt or lignite. Air-floated ball clays are now supplied for specifications which require a residue of not more than 5% on a 100-mesh screen and 25% on a 200-mesh screen; their moisture content must also be between 3 and 6%.

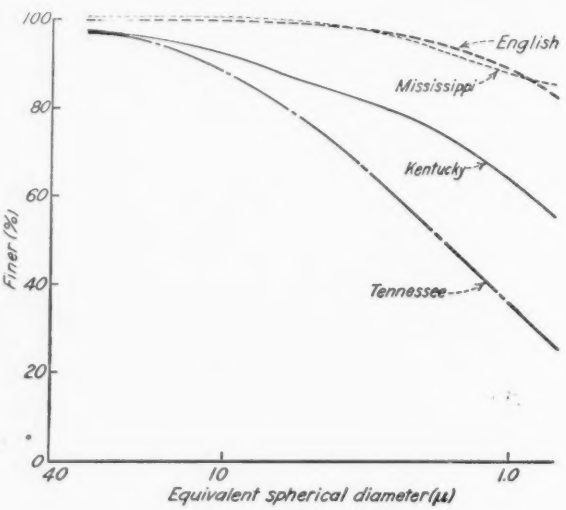

Fig. 2.—Grain size of ball clays.

* Received April 22, 1942.

[1] F. H. Norton, "Critical Study of the Differential Thermal Method for the Identification of the Clay Minerals," *Jour. Amer. Ceram. Soc.*, **22** [2] 54–63 (1939).

[2] Ernest Watkin, "Electrical Porcelain: Effect of Varying the Composition of Some of Its Properties," *Trans. Ceram. Soc.*, **23**, 186–210 (1924); *Ceram. Abs.*, **4** [5] 139 (1925).

(C) Casting Bodies

The amount of ball clay in casting bodies varies from 20 to 25%. The dark ball clays are more satisfactory because they contain organic electrolytes and organic matter and their high base-exchange capacity increases sensitivity to the electrolytes and increases the fluidity of the slip. There are slow- and fast-casting dark ball clays, whose rates of casting depend largely on the grain size of the clay (Fig. 2). Some dark English ball clays are too fine grained and therefore are not suitable for casting large pieces with heavy cross sections (some of which are more than 4 in. thick). Some dark Tennessee and Kentucky ball clays give excellent results.

When the casting slip is prepared by wet-grinding in ball mills, the amount of soluble salts is important. Calcium and magnesium sulfates may interfere with the deflocculation of the slip, but the addition of a barium compound will usually overcome this difficulty. A blend of ball clays is more desirable than a single clay and has resulted in a more uniform behavior and casting rate for the slip.

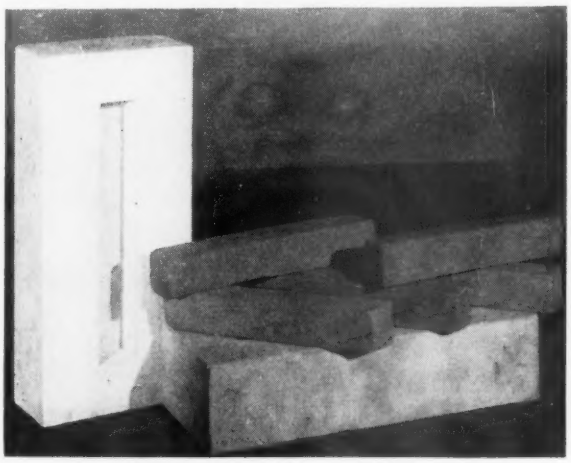

FIG. 3.—Molds and clay bars.

III. Methods of Testing Ball Clay

A 10-lb. sample from each carload is tested in the General Electric laboratory. Most of the test methods described in the Book of Standards of The American Ceramic Society (June, 1928) are used.

For molding the usual 6- by 1- by 1-in. clay bars, however, plaster molds are used (such as those shown in Fig. 3). The use of these molds speeds up the drying of the clay bars.

A number of special (not standardized) tests are also carried out, the more important of which are described as follows:

(*A*) *Test for Soluble Salts in Ball Clay:* From a larger sample of dried, crushed, and screened clay, a 1-gm. sample is boiled in distilled water for $^1/_2$ hr., and the solution is filtered and washed. The filtrate is made slightly acid with hydrochloric acid, and 10 cc. of a 1% barium chloride solution is added. The solution is boiled down, and the precipitated barium sulfate is dried on filter paper and weighed. Domestic ball clays contain from 0.2 to 0.4% of soluble salts (SO_3).

(*B*) *Test for Grain Size:* The Casagrande hydrometer method[3] is used and, occasionally, the Andreasen sedimentation pipette method.[4]

(*C*) *Test for Fired Color of Clays and Bodies:* Color tests of fired specimens $2^1/_2$- by $3^1/_2$- by $^3/_8$-in. thick are made on

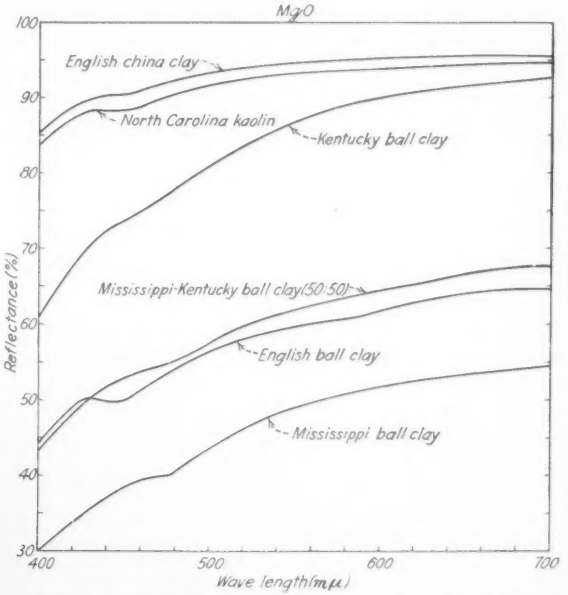

FIG. 4.—Color test for ball and china clays.

the General Electric recording spectrophotometer.[5] The surface of the fired specimen to be tested must be ground, especially when ball clays are used, for the surface is often slightly discolored owing to the formation of a scum. The

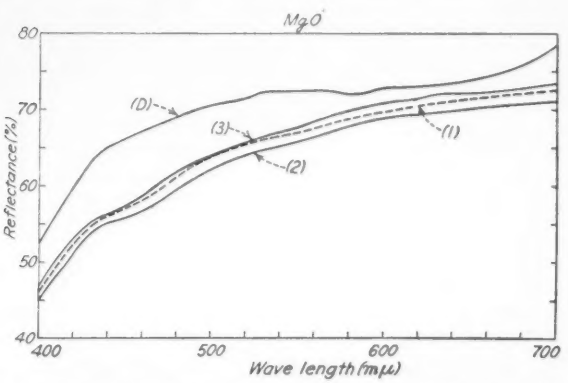

FIG. 5.—Color test. *Curve D:* dry-process porcelain (12% ball clay). Wet-process porcelain: *curve (1)*, English ball-clay body (27%); *curve 2*, Mississippi ball-clay body (27%); *curve 3*, a 50% Mississippi and 50% Kentucky ball-clay body (27% ball clay).

[3] J. C. Reimers, "Application of the Hydrometer Method of Fineness Analysis to Porcelain Enamel Slips," *Bull. Amer. Ceram. Soc.*, **18** [6] 195–200 (1939).

[4] G. A. Loomis, "Grain Size of Whiteware Clays as Determined by the Andreasen Pipette," *Jour. Amer. Ceram. Soc.*, **21** [11] 393–99 (1938).

[5] J. L. Michaelson and H. A. Liebhafsky, "A New Spectrophotometer and Some of Its Applications," *Gen. Elec. Rev.*, **39** [9] 445–50 (1936); *Ceram. Abs.*, **16** [4] 124 (1937).

percentage of reflectance at the visible spectrum (wave length between 400 and 700 mμ) of four ball clays and two china clays is shown in Fig. 4. The reflectance curves in Fig. 5 show the effect on the fired color of these ball clays in high-tension bodies. A white dry-process body, which contains a cobalt stain, is added for comparison. Although the individual ball clays differ considerably in color, this difference is less noticeable when they are used in a body composition.

Such spectrophotometric tests provide an accurate and permanent record of the fired color of clays and porcelain bodies.

PORCELAIN DEPARTMENT
GENERAL ELECTRIC COMPANY
SCHENECTADY, NEW YORK

TESTING BALL CLAYS FOR LOW-TENSION ELECTRICAL INSULATORS*

BY ARTHUR J. BLUME

Low-tension porcelain is formed by dust pressing. The body, which contains from 15 to 18% of water, is pulverized into dust and is formed by pressing in steel dies. Many of the pieces have small dimensional tolerances, and variations in the shrinkage of the body must be kept to a minimum. Drying shrinkage is influenced by the amount of moisture in the dust. When a ball clay is used which has high water of plasticity, the moisture content of the dust will be high, and a high drying shrinkage will result. The water of plasticity and the drying shrinkage of the ball clays therefore must be known.

Many dry-press pieces are complicated in shape and section. The body must (1) have good flow properties or good mobility so that it will flow around the intricate parts of the die without using excessive pressure and (2) be strong enough in the plastic state so that it will not tear or crack while being removed from the die. Plasticity involves two properties, namely, (1) mobility and (2) cohesiveness or stickiness. Ball clays, in their effect on these body properties, are the most important of the raw materials used. A test method that would give a numerical value to these properties would be most valuable.

The more intricate dry-press pieces are cleaned, i.e., mold marks or flash are removed after drying. The dry body should be strong enough so that the pieces can be cleaned, glazed, and placed in the kiln without undue breakage. If the body is too tough, however, cleaning is difficult. There is a close correlation between the dry strength of the body and the stickiness of the ball clay used, and a standard dry strength test might be a sufficient indication of stickiness.

The properties mentioned thus far pertain to the unfired body. Tests made on pure ball clays are often inconsistent with the results obtained when the clays are incorporated in the body. It might be well to make tests of the ball clays in combination with the other commonly used materials. As more than 25% of ball clay is seldom used, a standard body for test purposes might be set up as follows: feldspar 25, flint 25, china clay 25, and the ball clay being tested 25%. Except for the ball clays, the other materials should be standardized as to grain size, source, etc. If all of the ball clays were tested in this standard body and the data were listed, a fair idea of the properties imparted by each clay when incorporated in commercial bodies would be obtained.

The fired body properties are also affected by the ball clays used. Some ball clays are more prone to black core than others. A determination of the carbon present is a good indication of this tendency.

Firing shrinkage at various temperatures should be determined.

The transverse and impact strengths of the fired body are functions of all of the materials used. Ball clays vary widely in their fired strength at different temperatures. Here again data on the pure clay do not tell the whole story, and a fired strength determination of the ball clay in combination with other materials would be advantageous.

The fired color is influenced by all of the raw materials, and impurities in ball clays may darken an otherwise white body. The color depends on temperature, so that color data should be listed at different temperatures.

All commercial kilns are subject to some temperature variations, and a wide firing range in the body is necessary to insure vitrification and low absorption. Ball clays vary in firing range, and data on vitrification, together with information as to where overfiring begins, should be made available.

The properties to be checked which are imparted to the body by ball clays are as follows: *Unfired properties:* drying shrinkage, water of plasticity, mobility, stickiness, dry strength, and percentage of carbon; *fired properties:* firing shrinkage, fired strength, color, and firing range.

SQUARE D COMPANY
PERU, INDIANA

* Received April 22, 1942.

Discussion

L. E. THIESS: Mr. Blume, what test pieces are you using now for mechanical tests?

A. J. BLUME: We mix body materials in electrical mixers to make a commercial size of batch. The dust is prepared in the usual manner, taken to the press, and made into the test bar. Tests are made on dry strength, dry shrinkage, and moisture content; the bars are then fired and tested, including the Seger slump test.

L. E. THIESS: What is the size of the test bar?

A. J. BLUME: The bars are 9 by $^1/_2$ by $^3/_4$ in.

D. E. POSTLEWAITE: What is the purpose of determining the carbon content of the ball clay?

A. J. BLUME: Large pieces of porcelain tend to black core if a high percentage of carbon is present in the body.

F. K. PENCE: Has bentonite been tested for its "stickiness" properties in the body?

A. J. BLUME: No.

G. D. FORD: How is the carbon content in ball clay determined?

A. J. BLUME: No definite determination is made We make up standard bodies and fire a certain heavy piece.

Symposium on "Testing and Classification of Ball Clays"—Consumer's Viewpoint

USE OF BALL CLAY IN SANITARY WARE*

By James R. Beam

Opinions on ball clay are apt to vary considerably, depending on the amount of ball clay in the particular type of body under consideration. Ball clays are a necessary addition to most ceramic bodies and have their good as well as their bad points.

In the low ball-clay content bodies, many troubles are experienced by treating ball clay as an ordinary clay and by failing to give it the special control a larger amount of ball clay would justify.

In the manufacture of vitreous china sanitary ware, ball clay is the backbone of the casting body. All other ingredients are secondary and are balanced to fit the particular ball clays used. Experience has proved that this is the best conception in the development of several types of sanitary bodies, perhaps because of the abnormal influence of ball clay on both the casting and firing properties of a body.

Most sanitary-ware pieces are made by a combination of solid and drain casting. With this type of fabrication, it is imperative to control closely the casting properties of the slip. The "clay condition" of the solid cast must be the same as that of the drain cast. The rigidity of the plastic clay at the time the mold is opened should be the same in all portions of the piece. The inhibiting character of the ball clay makes this possible and allows drying operations to start from a common ground.

Drying problems in complicated pieces are of major importance, and the minimizing of drying stresses often determines the success or failure in producing a piece of ware. Drying problems are essentially ball-clay problems; the ball clay acts as a retarder to allow reasonable control over the drying. In a casting body that is not properly balanced, the thick sections will not cast solid, and casting defects will immediately result in drying cracks. The interrelation of the type of mold construction, the method of making ware, and the casting slip used in producing the piece of ware makes a complex picture patterned largely on what can and cannot be done with the ball-clay constituents.

Ball clay is the dry strength producer. A casting slip must be designed so that at the time the mold is opened the clay will set up with sufficient strength to retain the desired shape. The cast must be firm but not too dry or too hard to prevent proper sticking-up or finishing operations.

Ball clay is a natural colloidal material and as such follows all the erratic behavior of colloids, which absorb soluble salts in their natural state and are greatly affected by electrolytes both in their buffering and in their flocculating-deflocculating properties.

The physical properties of a ball clay in high ball-clay bodies exert such a profound influence over the body mix that once the proper ball-clay properties are worked out it is comparatively simple to complete a satisfactory body. Substitutions can be made in the washed kaolin constituents and in the nonplastic portions of a body much easier than in the ball-clay portion of the body.

The fusion characteristics of ball clays vary considerably in P.C.E. values. In sanitary ware, the product must be absolutely vitreous. Any change in the vitrification of the ball clay will correspondingly affect the vitrification of the body, and to balance for zero porosity, the plastic-nonplastic ratio of the body must be adjusted by altering the fluxing materials.

Some adjustments can be made by substituting such materials as Garspar or by adding auxiliary fluxes. Aside from the regular fluxing ingredients, the principal effect on vitrification is produced by ball clays which in themselves are of the open type or of the type that vitrifies to a certain extent at the temperature at which the body is fired.

The usefulness and potential possibilities of ball clay are intimately associated with the present investigations on their colloidal behavior. As our knowledge of the colloidal nature of this type of clay increases, its usefulness will increase.

Universal Sanitary Manufacturing Company
New Castle, Pennsylvania

* Received July 16, 1942.

USE OF BALL CLAY IN VITREOUS HOTEL CHINA BODIES*

By R. E. Gould

In the manufacture of hotel china there are several physical properties of the finished product which are of paramount importance, viz., (*a*) mechanical strength, (*b*) quality of the fired color, (*c*) a high degree of vitrification, (*d*) the quality of the finished piece of ware, and (*e*) translucency. Consequently all ingredients put into the body must be carefully scrutinized as to their final effect on these properties, and the amount of each material must be controlled to give the best combination consistent with practical manufacturing.

Viewed from this angle, ball clay in general has a detrimental effect on all of these properties; in some instances, however, it may help promote a longer range of vitrification. It is probably safe to say that no ball clay has so good a fired color as a high-quality china clay, and there is even a rough inverse proportion between the amount of ball clay added to any body and the quality of the final fired color.

The effect of ball clay on the translucency is, in general, detrimental. The amount of translucency is reduced, and the color of the light transmitted through the section is apt to be a brownish rose if the ball clay is present in a large enough amount. In ordinary sections, increasing amounts of ball clay contribute materially toward an

* Received April 22, 1942.

almost complete opacity of a vitreous hotel china body.

Experiments run at the Buffalo Pottery have not conclusively proved any connection between the amount of ball clay and the mechanical strength of the finished piece, as judged by chipping and impact values. No laboratory work or laboratory specimens have been used, and the work thus far has been confined to standard 7-in. rolled-edge plates and Ovide cups tested according to the National Bureau of Standards specification MC-301. Results of this test work so far are voluminous and indicate that the effect of ball clay on the fired mechanical strength of plates and cups is obscured by the shape of the final piece and other design features. It is definitely indicated, however, that a high ball-clay content is not specifically injurious to fired strength.

Tests run at various bisque firing schedules indicate that the failure to oxidize properly, to form so-called "sand spots," and to cause difficulties in general (as, for instance, when wet ware is fired at a fast rate) is not necessarily dependent on or connected with the percentage of ball clay. This observation was checked at different firing schedules in control batches whose entire clay content was made up of ball clays. The contention, therefore, that a high ball-clay content necessitates a slower schedule is not wholly true, at least in this instance and within the scope of the firing speeds thus far attained.

Ball clays are thought to be important additions because they are the clays which contribute most to the good workability and plasticity of the bodies. Low costs and high production demand a smooth working body which can be jiggered, cast, and turned at high speed. The smoothness of working, plus the ability of the clay being jiggered to polish under the tool, is also believed to have a beneficial effect upon the final fired piece; it is one of the factors, for example, which influences the final straightness of flatware. Not the least of all considerations in potting is the bisque loss which is roughly inversely proportional to the modulus of rupture of the unfired body.

The foregoing factors indicate that there are definite limits of the ball-clay content in a good-quality vitreous hotel china body. The ball clay chosen naturally must be the best combination of fired color, plasticity, and strength. Assuming that a good clay or clays have been found, a ball-clay content of from 7 to 8% seems to be an average figure, with a possible upper limit of 10 to 11% with some types of ball clays whose fired color is good but whose green strengths are low. For cheaper types of bodies, the ball-clay content could be increased up to 15 to 20%.

Ball clays have steadily improved in their quality and closer adherence to specified physical properties. Large storage, disintegrating, and thorough mixing have stabilized these clays and have also aided in obtaining drier clays so that freight is not paid on useless water. The various mining companies are to be highly commended for making all of these improvements possible. There is a need, however, for research in refining ball clay so that a better and cleaner product may be obtained. An easier working and a cleaner final body should pay for the additional costs, provided this is within reason. The ball clays could be thoroughly blunged, carefully screened, mixed with about 70% of standard flint, filter-pressed, and dried. The flint would be added only to permit filter-pressing within a reasonable time.

BUFFALO POTTERY, INCORPORATED
BUFFALO, NEW YORK

Discussion

R. E. GOULD: I was talking recently with a man who has a great deal of ability and knowledge in clays. He suggested that the producers would gain a lot if they would insist on a more careful and thorough drying. Our company has just purchased an expensive ball-clay washer, and I was interested and irritated to see the difficulty that we had to dissolve the ball clay in this washer. It took hours to reduce the clay, and we knew that if we could dissolve this ball clay more quickly we could double or treble the capacity of this machine.

Careful drying does not detract from the physical properties of the body. The ball clay back in the bins is practically bone dry, and we have observed no detrimental effect in the physical properties of the body except in slaking down, which takes only a few minutes against a matter of hours with the other process.

O. C. RALSTON: It requires hours to soak a glue so that it will function. It is the same thing with any colloidal clay except bentonite, which slakes in a short time. A well-known trick among ceramists is to use warm water under such conditions.

I want to record an experience with a very colloidal clay mixed with diatoms from a lake bottom. A soaking for 30 days in cold water failed to disburse the clay thoroughly so that it was free from the diatoms, but 30 minutes of soaking at about 80°C. did a much better job.

R. E. GOULD: Mr. Ralston, I feel that in this particular instance there is no direct analogy to these things. Everyone who has tried to slake down ball clays containing 15 or 20% of moisture versus dry ball clay sees there is no connection between that and the glue; the absorption of the one goes down like an aspirin tablet and the other is like liquid mud on the bottom of a pond.

O. C. RALSTON: When chunks of dried ball clay are wet, they swell to some extent. If the chunks are too big, you will get a swelled layer protecting an inner core; it is the same way with glue. You can get swelled glue which protects the inner cores of dry glue. I am using the word "glue" because "colloid" is simply the Greek word for glue and the ball clay is presumably the active or colloidal fraction of clay. I insist on carrying the analogy.

L. E. THIESS: Mr. Gould, does dry clay slake much faster than a clay containing about 20% of water?

R. E. GOULD: Yes, much faster. It is so marked that there can be no question about it.

L. E. THIESS: We find that ball clays with 20% of water, especially the fat clays, take a long time to disintegrate. If they are shredded and dried down to 15% or even below, they slake faster.

J. R. BEAM: Is not the effect of air film around the colloidal particle a factor in this slaking operation? We made some experiments several years ago in evacuating a ball mill with ball clay in it. The specific gravity curve, under the evacuated condition, showed a slaked condition in about one third the time ordinarily required. There was also an appreciable amount of air coming from the mix.

If the air film is recognized as being a constituent in a clay-water mixture, the quickest way to obtain a "smooth" blend is to remove the air film and to allow the water to contact and surround the colloid.

HARRY THIEMECKE: You must also take into consideration the fact that when the water goes into the ball clay, particularly the dry ball clay, owing to the capillary attraction, it displaces the air that is in there. The water has gone in there at a terrific rate; it displaces the air in a hurry so that there is more or less of an explosive effect. When the air goes out, it kicks off chunks of clay and you get faster slaking.

Symposium on "Testing and Classification of Ball Clays"—Consumer's Viewpoint

FUNCTION OF BALL CLAY IN VITREOUS BODIES*

By Edward Schramm

It has been well pointed out by Mr. Gould that the effect of ball clay on the finished product is undesirable, yet its use is universal. It contributes indispensable benefits in processing by (1) aiding vitrification. Ball clay has an effect seemingly disproportionate to the actual content of fluxing elements owing to the extreme fineness and perfect distribution of the fluxes in the clay. In American practice, china (or porcelain) is fired at temperatures considerably lower than in Europe. This is made possible by the use of auxiliary fluxes such as whiting or dolomite which shorten the firing range. A moderate amount of ball clay aids the auxiliary flux to assist in vitrification and at the same time widens the firing range.

(2) The more essential function of the ball clay is its effect in improving the flow properties of both plastic clay and casting slips. In enumerating the properties of ball clays, Watts has listed strength or toughness and "oiliness" or lubricating qualities (see p. 249). Some of the secondary kaolins have considerable dry and plastic strength, and these properties could probably be obtained in adequate measure without the use of ball clay. In contrast, the flow properties of the ball clays are not shared by the kaolins, and it may fairly be said that these are the most characteristic and essential properties.

Owing to their geologic history, ball clays have a high proportion of fine grains and a considerable admixture of organic matter which includes solid lignite. In an extended trial, the ball-clay content of a china body was ball milled, thus including the ground lignite in the body. Instead of improving the plastic properties, the body was rendered decidedly "short." It must be concluded, therefore, that the significant organic matter is that present in soluble or colloidal form, and the clays owe their properties to these colloids in conjunction with their fine particle size.

It has been practically impossible to produce good casting slips without the use of some ball clay in the body. Ball clays differ greatly in their effectiveness. Thus it was found that better fluidity could be obtained with a black English ball clay than with a blue English ball clay. Only small amounts need to be used, as a law of diminishing returns operates. The problem in producing vitreous china is to limit the ball clay to the amount essential for forming and thus minimize its harmful effect on the finished product.

In view of the controlling importance of the plastic properties of ball clays, the beneficiation of the clays seems to be important. The English clays are usually shipped wet. There is a tendency now to dry and pulverize the clays. It is an advantage to the consumer to have such prepared clays, but they may detract from the essential character of the ball clays which are needed for plasticity.

* Received June 18, 1942.

Onondaga Pottery Company
Syracuse, New York

Discussion

R. B. Carothers: When ball clays are discussed, they should be called by name as individual materials. For instance, the name "Kentucky ball clay" is used. Kentucky ball clays vary as much as the Kentuckians, and you get a lot of wrong ideas. It would help the producers as well as the consumers if the clays are specified.

Dr. Schramm said ball clay is a necessary evil. I want to state that ball clay is like whiskey—some people can handle more than others.

Chairman Russell: Mr. Carothers, do you propose that we call all of these ball clays by their individual names?

R. B. Carothers: If you show a slide on the screen and call it Kentucky ball clay, a lot of the youngsters in the industry who have not had much experience may get the idea that all Kentucky clays have that particular characteristic, which is not true.

Chairman Russell: That is a good suggestion and it is heartening, too, that a producer would propose it. We have been somewhat concerned about how we are going to keep from stirring up some of the ball-clay producers when identifying names are listed with data. I do not see why anyone would object to having a material publicized unless there is an attempt to market something inferior, and I trust that no such condition exists.

R. C. Meeker: Dr. Schramm raised a point about drying clays in connection with pulverizing and the possible damage to them. In drying ball clays, particularly the carbonaceous clays (where the carbonaceous matter is intimately associated with the clay), there is a danger of destroying the plasticity of this particular type of clay if, after the moisture is driven off, the temperature is held at 20°C. for 25 or 30 minutes or longer. Certain types of clays in this class will have definitely lost their plasticity. They will turn to the color of lignite, and slaking action will be at least partially destroyed and retarded.

In air-floating clays, the kiln mill type of pulverizer is sometimes used, that is, hot gases are introduced into the mill when drying and air-floating the clays. Although gases are introduced at a very high temperature into the mill, a tremendous decrease occurs immediately inside. Gases may enter at 1000° to 1200°F., but immediately, in a distance of about 4 feet in the mill, the temperature will drop to about 175°F. This is a flash heat-treatment and so far as we have been able to determine from our own observations and from those who are using air-floated ball clays, there is no measurable destruction of the plasticity.

L. E. Thiess: I have found no reduction of plasticity in the air-floated clays. We have used some in dry mixers and have extruded some of the plastic bodies in pug mills. In air-floated clays, especially those used for plastic bodies, dirt and carbon must be kept out as much as possible. There are not many clays on the market at the present time that contain a large amount of lignite. Certainly it cannot be washed out because there is no washing process in dry mixing.

O. C. Ralston: This question of drying the glue to be used seems to be a rather important point. Any powdered glue that is dried takes time to soak before it swells and becomes a glue again. Those who may not have noticed loss of stickiness or plasticity even in a "dry" mix, which really is not dry, probably have had a sufficiently long-time factor so that they have had no difficulty, whereas the men who have noticed difficulties have started immediately to work on the mix instead of letting it stand a while to allow the moisture to have a chance to slake or swell the colloid.

L. E. Thiess: We have even found an increase in plasticity. Some dry-mixed bodies made from air-floated ball clays, having a moisture content of 17%, were more sticky and difficult to pulverize satisfactorily for dust-pressing than the same bodies made by wet-blunging and filter-

pressing. We had to reduce the moisture content to disintegrate the body properly. In wet-blunging, a deflocculating action occurs, which is caused by soluble salts from the feldspar. The time element is important; most manufacturers age the pulverized body for 24 hr.

A. L. JOHNSON: Dr. Schramm, do you attribute a lot of the plasticity to the soluble organic material?

EDWARD SCHRAMM: Yes, that is the point I have been trying to make.

A. L. JOHNSON: I am not an advocate of dispensing with the filter-pressing of the body before the second slip is made, but is much of the so-called soluble material being removed in the filter-pressing operation?

EDWARD SCHRAMM: Probably not so much as you think.

A. L. JOHNSON: If the material is soluble, it would not be attached necessarily to the clay particle. There is a difference between soluble material which may be admixed with the clay and the adsorbed material.

EDWARD SCHRAMM: This is difficult to prove. We put soluble cobalt sulfate into bodies as a stain. The cobalt sulfate is perfectly soluble, but it does not go out in the filter-press water.

R. C. MEEKER: Dr. Schramm, you spoke about your experience with lignite. I think that might depend upon the type of lignite which occurs in the ball clay. I can conceive of a lignite, which is almost pure carbon with very little clay substance in it, that would give you the experience that you had. If you use a lignitish residue that is found on your lawn which has a high percentage of clay, it might yield better results.

EDWARD SCHRAMM: This experiment was carried out only with one clay. It happened to be a black English ball clay which contained between 5 and 10% of lignite. That is the quantity that would normally remain on the lawn.

R. C. MEEKER: Did the lignite look almost like coal?

EDWARD SCHRAMM: It was little dark pieces of wood.

R. C. MEEKER: There is this type of lignite in some English ball clays.

HANS THURNAUER: Isn't the trouble with the lignitic clays caused by the pitch which accompanies the lignite?

CHAIRMAN RUSSELL: It is true that the organic constituent in the ball clay is a contributing factor to plasticity, but it is not the only factor. This discussion on lignite merely emphasizes the fact that we do not know very much about ball clays and why they are ball clays. I doubt that any of us is qualified to give a complete answer at this time. We are undertaking this entire investigation in an attempt to derive some of the answers.

Discussion on Semivitreous Whiteware

J. W. HEPPLEWHITE: Harry Thiemecke and I agree with the former speakers in substance as to the desirable properties imparted by ball clay. We also agree with Dr. Schramm that ball clay is indispensable, but ball clays are like some relatives—we inherit them with their idiosyncrasies, but we must battle with them. The chief difficulty is that classified clays have not made their commercial appearance.

Another point is that of the water content of the clay when it is delivered. I have records covering the average maximum-minimum water content of ball clay shipments for the past two and one-half years. We have obtained ball clays with a water content as high as 26 and 28% and as low as 10½%, with averages from 17 to 23%. This is important, owing to the increase in freight rates, which, I believe, is 3% or more at the present time.

We are going to ask the producers a question although it is not necessary for them to answer it now. What can be done to clean up a ball clay without impairing its desirable qualities? Ball clay could probably be delivered to the plant so that the entire slip house operation could be eliminated. You could thereby eliminate the use of sacks (which are really a sacred article) as well as screens and sliphouse equipment, which have a high maintenance and operating cost.

R. B. CAROTHERS: Mr Hepplewhite probably has a hard job running a sliphouse. He wants to give the job to me. We could get the sacks, but we do not know yet what he wants done.

J. W. HEPPLEWHITE: We could give you the job of running the sliphouse and not pay the freight on excess water in the material.

R. B. CAROTHERS: That is true, but before you ask some poor producer to put up a plant to clean the ball clay, you should find out what kind of a clean-up job you want done. You might injure the clay. There is a wide variation of opinion as to what would happen if you took some of these things out. Al Gerber talks about buying some of this stuff and adding it to some of the clays; but this is the same thing that other consumers are complaining about being in there. There is a wide variation of opinion as to how much moisture ought to be in the clays when you get it. As soon as the consumer lets us know what he wants, maybe we can get it.

J. W. HEPPLEWHITE: Probably I should rephrase my question. Instead of saying "What are you going to do?" we say, "What have you done?"

R. B. CAROTHERS: We haven't done anything yet.

R. E. GOULD: I would like to ask the producers for an expression of opinion as to whether it would be a practical idea to dry the clay slowly and easily down to about 5% of water. Would that be possible?

R. B. CAROTHERS: I don't know; some of you fellows tell me drying is a simple mathematical problem. It just takes so many B.t.u. to kick out so much water. We have done a little figuring on this question, and some of our customers have checked on it at different times. Thus far we have always come to the answer that the cost of mechanical drying of clay exceeds the saving in freight that would be made. So it is economically the wrong thing to do. Possibly that won't always be true. Freight rates are getting higher and eventually it may be economically the thing to do.

CHAIRMAN RUSSELL: This whole question can be reduced as follows: When the consumer decides what he wants and specifies it, the producers then will try to give them the materials that are specified, provided, of course, that a sufficient number of consumers require the specified material.

This point brings us to the urgent need for a ball-clay specification. The consumer should record his requirements, which he will then set forth to the producers.

Classification of Ball Clays by Means of Fundamental and Physical Test Data

CHAIRMAN RUSSELL: This topic was to have been presented by J. H. Koenig. Dr. Koenig could not be present and has had no opportunity to prepare a discussion. For this reason, I shall outline our joint ideas on this subject.

As mentioned previously, one of our primary objectives is to correlate fundamental properties with some of the more common physical test properties which are determined in most plants and laboratories.

There are five fundamental properties which we have classified as such, but others may be added if such recommendations are made. These fundamental properties are those which possibly contribute in large part to the characteristic properties of ball clays.

The first property is grain size. It is undoubtedly true that the particle-size distribution and the colloidal character of clays are important factors in the control of their properties.

The second factor is the soluble salt content and the pH value, properties which are somewhat related. These factors are important, especially in controlling the plastic properties.

The third property is the amount and character of the exchangeable bases. Numerous investigations have shown that the character of these bases as well as the amount greatly influences the properties of clay in the plastic and fired states.

The fourth property is the amount and condition of the organic material, which has been discussed here to some extent. We consider this to be very important.

The fifth property that might be included is the chemical and mineralogical composition. How these factors control the properties is not well understood, but it is logical to assume that they are important.

In addition to the five fundamental properties listed, there may be others equally important. As mentioned before, we hope to correlate these fundamental properties with some of the common physical test properties which are usually determined in laboratories. Such tests include the determination of plastic properties, water of plasticity, shrinkage, transverse strength, and various fired properties. We hope to carry this investigation sufficiently far to be able to show why different clays have characteristic properties, and, if possible, to recommend simplified test methods that will enable a consumer to select the best clay for his particular need as a result of his own tests.

PARTICLE-SIZE DETERMINATIONS*

By G. A. Loomis

Various methods of measuring the subsieve particle size of clays and other ceramic materials have been employed or proposed for use. Those methods worthy of note are mentioned briefly; the most familiar method is described in greater detail.

(1) Elutriation

Elutriation was one of the first methods employed. Good results were obtained by Schurecht,[1] who used an improved Schultz elutriating apparatus.

(2) Ordinary Pipette Method

This method, first proposed by Robinson,[2] has been used for years by the soil chemists when a high degree of accuracy is required. It has also been used as a standard of reference for other methods.

(3) Hydrometer Method

This method has been used by soil chemists for about fifteen years and is generally preferred in determining the particle size of clays because of its simple operation and reasonable accuracy. Bouyoucos[3] was among the first to describe its use. A similar method developed later by Casagrande[4] is now extensively employed.

The pipette and hydrometer methods both depend for their accuracy on the validity of Stokes' law. In making separations below 0.5 micron, the centrifuge has been used in combination with both of these methods[5] because separations by gravity below this limit become impracticable and Stokes' law does not operate.

(4) Sedimentation Tube Method

The Kelly tube,[6] which illustrates this method, apparently has no advantage over the hydrometer and is less reliable.

(5) Microscope Method

This method is probably the most accurate, but it is laborious and time-consuming if precise results are to be obtained.

(6) Wagner Turbidimeter

The turbidimeter[7] is used mainly for Portland cement, but it may be used for other materials. It has the advantage of speed, but it requires a calibration for each type of material used.

(7) Andreasen Pipette Method

This method is a refinement of the ordinary pipette method. The apparatus has been described fully and the procedure for its use has been given in detail in a previously published paper.[8]

The apparatus consists of (1) a glass vessel, which has a capacity of about 550 cc. when filled to the upper mark on the scale, and (2) a glass stopper. The stem of a 10-cc. pipette passes through the stopper and extends 20 cm. below its surface.

This method, as all methods which depend on the sedimentation of a suspension, depends for its accuracy on the validity of Stokes' law. It has the advantage of precision over other methods. The samples drawn at different intervals of time are evaporated to dryness, weighed accurately, and their particle size is calculated. An accurate basic curve is then drawn from which the percentages by weight between any desired intervals of particle size may be taken and shown graphically.

In any particle-size determination, the method of dispersing the sample is important. It should obtain reproducible and comparable results with all types of clays and yet not require too much time.

The sample needed to produce a 1% suspension in the apparatus (ball clays are crushed to 1/4-mesh) is weighed into a 250-cc. wide-mouthed bottle and 200 cc. of distilled water are added. The sample is allowed to soak for 24 hr. Then 10 cc. of a solution of tetrasodium pyrophosphate (24.55 gm. of $Na_4P_2O_7 \cdot 10H_2O$ in 500 cc. of distilled water) are added, and the bottle is placed in a tumbling machine and rotated end over end for 17 hr. Consistent results are thus obtained with all types of clays.

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(1942)

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[5] (*a*) R. H. Bray, "Significance of Particle Size Within the Clay Fraction," *Jour. Amer. Ceram. Soc.*, **20** [8] 257–61 (1937).

(*b*) F. H. Norton and S. Speil, "Measurement of Particle Sizes in Clays," *ibid.*, **21** [3] 89–97 (1938).

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[8] G. A. Loomis, "Grain Size of Whiteware Clays as Determined by the Andreasen Pipette," *Jour. Amer. Ceram. Soc.*, **21** [11] 393–99 (1938).

A CRITICAL ANALYSIS OF STOKES' LAW AS A BASIS FOR THE DETERMINATION OF PARTICLE SIZE OF CLAYS AND NONPLASTIC MATERIALS*

By R. M. King

Abstract

Objectives desired in particle-size determination are discussed and examined with respect to their desirability and attainability. The influence of preparatory treatments of the clay sample on the distribution of particle sizes is reviewed. The errors and limitations of Stokes' law are considered, particularly with respect to the correct value for the density of the suspended material. Recently developed ideas on the colloidal chemistry of clays and on density determinations are used as a basis for this discussion.

I. Introduction

It has been traditional to consider the property of plasticity of a clay to be the result of extreme fineness of subdivision. It may be heresy, therefore, to suggest that this fineness of subdivision may be the result of plasticity, or, more specifically, the result of the same forces which contribute to plasticity. A discussion of this subject might well develop into a "which came first, the hen or the egg" argument, but recent research in the colloidal chemistry of clays justifies a revision of our thinking regarding many of the traditional conceptions of clays and their properties. This is particularly true regarding our ideas on particle size.

In a crude clay, it is necessary to distinguish between two types of particles of colloidal dimensions, viz., (1) particles formed by the mechanical disintegration of rock fragments and (2) particles formed by the interaction of hydrous oxides of silicon, aluminum, and iron with various bases which result from the chemical weathering of various minerals in the earth's crust. Particles of type (1) are abundant in glacial and residual clays and, to some extent, in other clays. The size of these particles is the result of mechanical accident, and they do not possess the property of plasticity or base exchange. Weathered material produces particles of type (2), which possess the power of base exchange and make up the bulk of the material showing the characteristic properties of clay. The size of these particles in a water environment cannot be accidental, but must be the result of an equilibrium between opposing forces, such as the force of cohesion and electrokinetic and osmotic forces.

When clay is suspended in water, it is necessary to distinguish between particle size and micelle size, for it has been well-established that particles are surrounded by a shell of immobilized water which moves with the clay particle as the atmosphere moves with the earth. A clay micelle is the particle plus the water shell plus the atmosphere of dissociated ions. Mattson[1] has shown that a clay with the smallest particle size may have the largest micelle, and vice versa. Thus a clay which is more highly dispersed than another clay may have the larger apparent particle size.

* Received April 27, 1942.

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II. Factors in Determination of Particle Size

Two factors are of paramount importance when considering the determination of the particle size of clays, viz., (1) the method of preparing the clay and (2) the method of determining particle size. As the particle size of clays as originally deposited has been modified undoubtedly by centuries of exposure to repeated wetting and drying, freezing and thawing, pressure, electrolyte-bearing surface and underground waters, and to decaying vegetable matter, it is improbable that any accelerated method of dispersion can undo what has been accomplished during geologic time. The original particle size of many clays, therefore, cannot be obtained readily. It is necessary to select a method of dispersion which gives reasonably reproducible results and to recognize that each method of treatment may produce a different particle size from the same clay and that even a carefully controlled treatment may not yield comparative results from clay to clay.

III. Methods of Preparation

Sodium carbonate and sodium oxalate are often used as dispersing agents to form an insoluble precipitate with the exchangeable calcium ions of the clay. This, of course, changes the clay from a partial calcium clay to a complete sodium clay and changes, therefore, the particle size of the calcium clay to that of a sodium clay. Clays with fewer or no calcium ions and more sodium ions would exhibit a relatively smaller change in particle and micelle size but might or might not produce the same relative or absolute size. The response of a clay to a given dispersing agent depends on the silica-alumina ratio as well as on the presence of humus.

Loomis[2] uses the Andreasen method of preparation and specifies 10 cc. of a 5% solution of sodium pyrophosphate in 550 cc. of a 1% suspension of clay. This reagent tends to precipitate the exchangeable magnesium ions and to form a sodium clay. Phosphate ions, moreover, are positively adsorbed by the clay complex and markedly change the fundamental properties of the clay. The assumption that comparative results will be obtained from clay to clay with a given treatment is therefore not justified. In other words, the action of a given quantity of electrolyte

[2] G. A. Loomis, "Grain Size of Whiteware Clays as Determined by the Andreasen Pipette," *Jour. Amer. Ceram. Soc.*, **21** [11] 393–99 (1938).

is not necessarily directly proportional to the particle size of a clay.

Johnson and Norton[3] employ a treatment in which the clay is electrodialyzed to remove exchangeable bases and treated with hydrogen peroxide and NaOH to remove organic matter and then electrodialyzed again to remove sodium ions. This treatment produces a material which gives uniform response in tests, but it should be borne in mind that the original clay has been changed both by electrodialysis and hydrogen peroxide and that the final product may be only remotely related to the starting material.

IV. Methods of Determining Particle Size

Several methods of determining particle size have been developed, but only those which use Stokes' law come within the scope of this paper.

The usual expression for Stokes' law is as follows:

$$V = \frac{2r^2g(d_1 - d_2)}{9K}.$$

Where V = velocity of settling of particles (cm./sec.).
r = radius of particle (cm.).
d_1 = absolute density of particle.
d_2 = density of suspending medium.
g = gravity constant.
K = viscosity of medium.

In a given system, all factors except V and r can be incorporated into the constant $V = Cr^2$.

Baver[4] summarizes the assumptions and limitations of Stokes' law as follows:

Assumptions

(1) "The particles must be larger in comparison to liquid molecules so that Brownian movement will not affect the fall."

(2) "The extent of the liquid must be great in comparison with the size of the particles. The fall of the particles must not be affected by the size of the particles."

(3) "Particles must be rigid and smooth."

(4) "Particles should be spherical, but the term 'equivalent or effective radius' is used to overcome this difficulty.... Equivalent or effective radius is defined as the radius of a sphere of the same material which would fall with the same velocity as the particle in question."

(5) "There must be no slipping between the particles and the liquid."

(6) "The velocity of fall must not exceed a certain critical value so that the viscosity of the liquid remains the only resistance to the fall of the particles."

Experimental Limitations

(1) "Since the rate of fall varies inversely with the viscosity of the medium, it is necessary to maintain a known constant temperature during the analysis."

(2) "A constant temperature helps also to prevent convection currents that might arise as a result of differences in temperature near the walls of the vessel and within the suspension. . . . Currents due to stirring are more difficult to eliminate than those caused by temperature variations."

(3) "The density of the soil particle is another factor that affects the accuracy of Stokes' law. Density depends upon the mineralogical and chemical constitution of the particles as well as upon their degree of hydration."

Corrections are made for most of these factors, or they are controlled as carefully as possible or recognized as an unavoidable source of error. The third limitation, density of the particle, has not received sufficient attention. In considering this, we are concerned with the factor, $d_1 - d_2$, in the Stokes' equation. As d_2 is the density of the suspending medium, no inaccuracy is involved in replacing this with the value for the density of water at the temperature of the test. Owing to hydration, the clay particle is surrounded by a shell of water which settles with it. The substitution of the absolute density of the clay particle for d_1 is therefore unjustified. The rate of fall of the micelle is being measured, and the value for density of the micelle should be used.

The following calculations indicate the error involved. Mattson[1] shows that in one soil the size of the particle was 26 $\mu\mu$ in diameter; the thickness of the water layer was at least 11 $\mu\mu$. A simple calculation shows that the ratio of the volume of the water layer to the volume of the particle is as 1.88 to 1.0. The generally accepted value for absolute specific gravity of the clay particle is 2.65. With the ratio of water to clay as given previously, the value used for d_1 should be 1.573 instead of 2.65. These data indicate the possible error involved, but this depends, however, on the thickness of the water layer, which is variable.

Norton and Speil[5] report a close agreement between particle sizes determined by the Casagrande hydrometer method and microscopic method. The Casagrande method apparently compensates for the error already discussed.

Another source of error involves d_1. Culbertson and coworkers[6] show that the density of a material in fine powder form varies with the liquid in which the density is determined. A dried silica gel has a density of 2.247 when determined in water, 2.310 in acetone, and 2.183 in benzene, thus showing a spread of 0.127. As these determinations can be made with an accuracy of at least ± 0.005, the spread is too great for experimental error. This difference seems to result from the specific relationship between a liquid and a solid which controls the thickness and density of a compressed film around the particle.

Although this error is not so great as that resulting from the hydration of the particle, in the accurate use of Stokes' law, a correction for this error should be considered even for nonplastic particles. Such a correction should be considered especially in precise immersion methods for density determinations.

V. Summary and Conclusions

Particles and micelles have been defined. Some meth-

[3] A. L. Johnson and F. H. Norton, "Fundamental Study of Clay: Preparation of a Purified Kaolinite Suspension, I," *Jour. Amer. Ceram. Soc.*, **24** [2] 64–69 (1941).

[4] L. D. Baver, Soils Physics, pp. 32–33. John Wiley & Sons, Inc., New York, 1940.

[5] F. H. Norton and S. Speil, "Fractionation of a Clay into Closely Monodispersed Systems," *Jour. Amer. Ceram. Soc.*, **21** [10] 367–70 (1938).

[6] (*a*) J. L. Culbertson and Alver Dunbar, "Densities of Fine Powders, I," *Jour. Amer. Chem. Soc.*, **59** [2] 306–308 (1937).

(*b*) J. L. Culbertson and M. K. Weber, "Densities of Fine Powders, II," *ibid.*, **60** [11] 2695–97 (1938); *Ceram. Abs.*, **18** [9] 254 (1939).

ods of preparation of clay suspensions for particle-size determination have been discussed in the light of their influence upon particle size. The shell of water surrounding the clay particle should be considered in particle-size determination, inasmuch as it influences the density value used in the calculation of particle size from the Stokes' relation. Other limitations involved in this relation and some errors in density determinations have been reviewed

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PARTICLE SHAPE AND THE BEHAVIOR OF CLAY AS REVEALED BY THE ELECTRON MICROSCOPE*

BY R. P. HUMBERT

I. Introduction

The wide variety of shapes exposed by electron microscope studies may now be used to interpret differences in properties of the clay minerals. The structures exposed in electron photomicrographs serve as another link in the more complete characterization of clay minerals. Their hydration, plasticity, bonding strength, base exchange, and other surface properties are closely correlated with the structural units. With a magnification ranging to 100,000 diameters, shape, size, characteristic crystal habit, and surface features of the clay minerals may be studied.

It is the purpose of this paper to present the electron microscope as a new tool for ceramic research. Characteristic photomicrographs of several clay minerals are presented, including three clays of ceramic importance.

II. Microscope Technique

In electron microscopy, the image formation is due to a scattering of the electrons. Because of the necessity of the transmission of the electron beam, the glass slides used in light microscopy must be replaced as specimen holders by extremely thin films. As electron scattering is proportionate to the thickness and density of the substance through which the beam is passed, the films supporting the specimens must be extremely thin and homogeneous. The films are prepared by spreading one drop of nitrocellulose in amyl acetate (approximately 2%) over a perfectly clean and quiet water surface. After the evaporation of the solvent, a thin film (< 100 a.u.) remains on the water surface. Small disks (2 mm. in diameter) of 300-mesh copper screen that have been carefully rolled to extreme thinness are dropped on the film. With the copper screen acting as a mechanical support, the film is retrieved with suitable holders and placed on a drying rack. The copper screen which holds the film is placed upon a clean blotter, and one drop of a < 1% suspension of clay in water is allowed to dry on the surface of the film. The disk supporting the film which contains the clay is placed in the specimen holder and then into the vacuum chamber of the microscope for observation.

III. Results

PLATE I. CLAY MINERALS OF THE 2:1 LATTICE TYPE

Figure 1 shows montmorillonite from San Diego County, Calif. The striking feature about this clay mineral is the vast amount of surface per unit mass. Although the particles have the appearance of amorphous aggregates, they are probably composed of extremely fine crystals.

Figure 2 represents nontronite from Sandy Ridge, N. C. It is similar to montmorillonite in that it exposes considerable surface, but its pronounced lathlike shape clearly distinguishes it from the latter. The penetration of the electrons through the crystals shows that the lath-shaped plates are relatively thin.

Figure 3 shows illite (known commercially as Grundite) from Goose Lake, Ill. The large particles in general have an appearance that resembles montmorillonite. A close examination, however, shows that each particle is an aggregate of small, well-defined crystals with pronounced micaceous cleavage.

Figure 4 is beidellite fractionated from the Putnam silt loam of Missouri. This clay occurs as thin plates with poorly defined edges and cannot be distinguished from beidellite from its type locality, Beidell, Colo.

Figure 5 shows a fraction which was prepared by O. J. Kelley[1] from Rock River, Wyo., bentonite. The particles are well defined, but close examination shows that each unit is composed of aggregates of extremely thin, plate-shaped crystals. Estimates of thickness based on electron penetration classify these crystals as unit cell structures. In the lower left-hand corner of Fig. 5, the position of the plate-shaped structural units illustrates the expanding action of the crystal aggregates on hydration.

Figure 6 is a sample of magnesium bentonite (hectorite) from Hector, Calif. Many of its properties, including extreme swelling on hydration and low chemical stability, can be explained by the fibrous nature of this clay mineral. The electron photomicrograph presents aggregates of fibers that have a tremendous surface per unit mass.

PLATE II. CLAY MINERALS OF THE 1:1 LATTICE TYPE AND COMMERCIAL CLAYS

Figure 1 represents kaolinite. This sample of English china clay was fractionated and studied by Shaw.[2] The thin, straight-edged, sharp-angled crystals are characteristic of kaolinite. Measurements of interfacial angles show that the 120-degree angles are a distinguishing feature of its crystal habit. The black dots in many of the crystals are not structural features of the kaolinite but are imperfections in the nitrocellulose film on which the kao-

* Received July 1, 1942. This paper is a contribution from the Department of Agronomy, the Ohio Agricultural Experiment Station, and Ohio State University. The research was carried out in the Radiation Laboratory of the Ohio State University.

[1] Doctor's dissertation, Ohio State University, June, 1942.

[2] B. T. Shaw, "Nature of Colloidal Clay as Revealed by the Electron Microscope," *Jour. Phys. Chem.* (1942); in press.

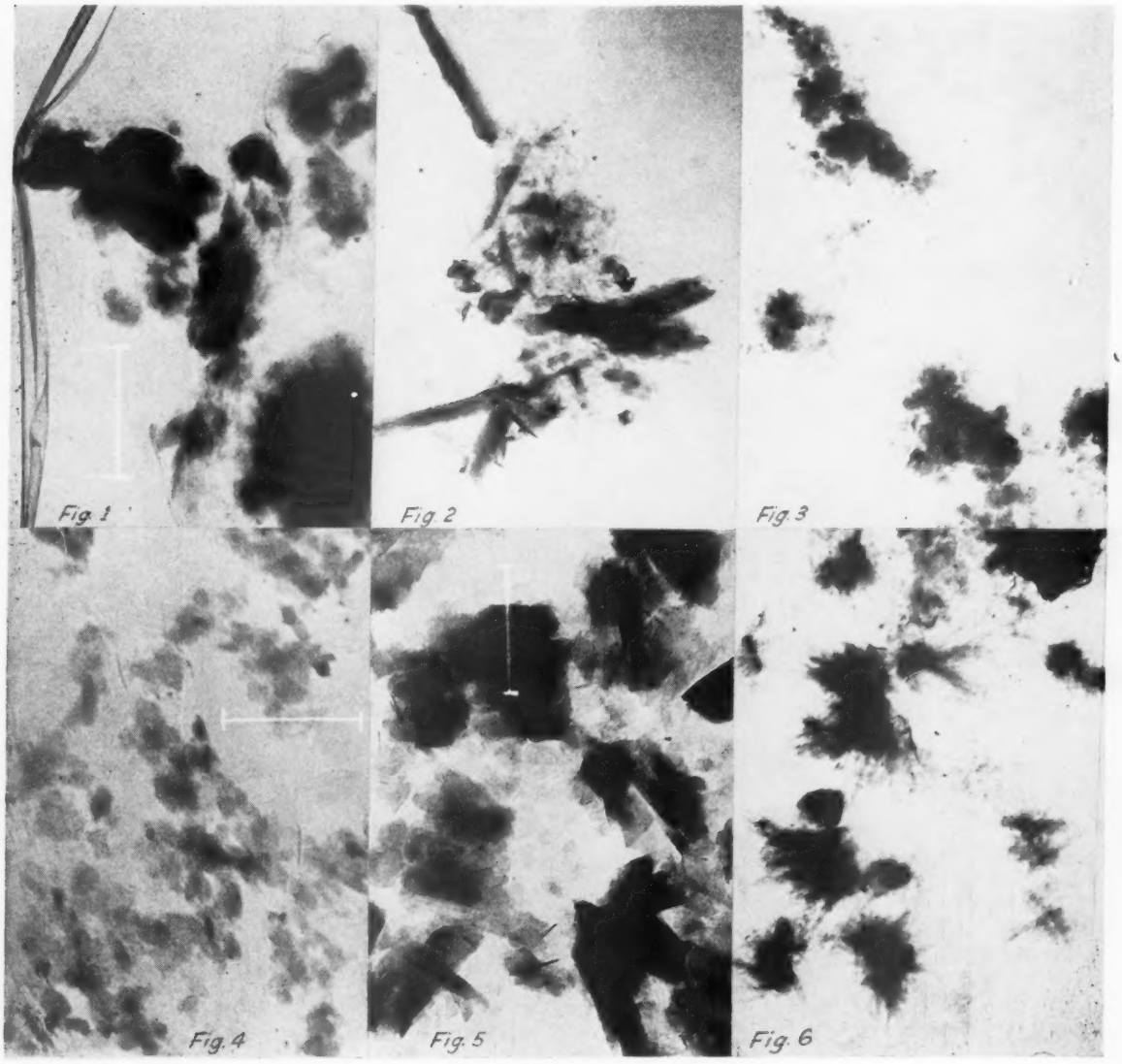

PLATE I

CLAY MINERALS OF THE 2:1 LATTICE TYPE

FIG. 1.—California montmorillonite. FIG. 2.—Nontronite. FIG. 3.—Illite. FIG. 4.—Beidellite. FIG. 5.—Wyoming bentonite. FIG. 6.—Hectorite. (Unit of measurement, 1 μ.)

linite is suspended. Variations in electron penetration through different thicknesses are well shown where there is an overlapping of crystals.

Figure 2 shows dickite from Chihuahua, Mexico. Most dickite crystals are sufficiently developed along the *c*-axis to be opaque to electrons. This thickness of plates distinguishes dickite from kaolinite. The distinct crystallinity is much more common in dickite than in kaolinite, but this characteristic must be used with discretion in identification.

Figure 3 represents halloysite from Maiden, N. C. The rod-shaped crystals are characteristic of halloysite from three different localities in the Piedmont and from one locality in Indiana.

Figure 4 represents the Sciotoville fire clay. Impurities are easily detected. The smaller opaque crystals are doubtless some of the more resistant heavy minerals and have settling velocities similar to the dominant larger and thinner plate-shaped clay minerals. Many of the larger opaque crystals compare favorably with the samples of quartz studied.

Figure 5 shows attapulgite, another fibrous clay mineral from the Attapulgus Clay Co., Attapulgus, Ga. Fractionation of this clay shows that the particles settle in a verticle position; the width of particles is involved, therefore, in establishing settling velocities. The fractionation of the mineral impurity follows Stokes' law.

Figure 6 shows a ball clay from the Mayfield, Ky., dis-

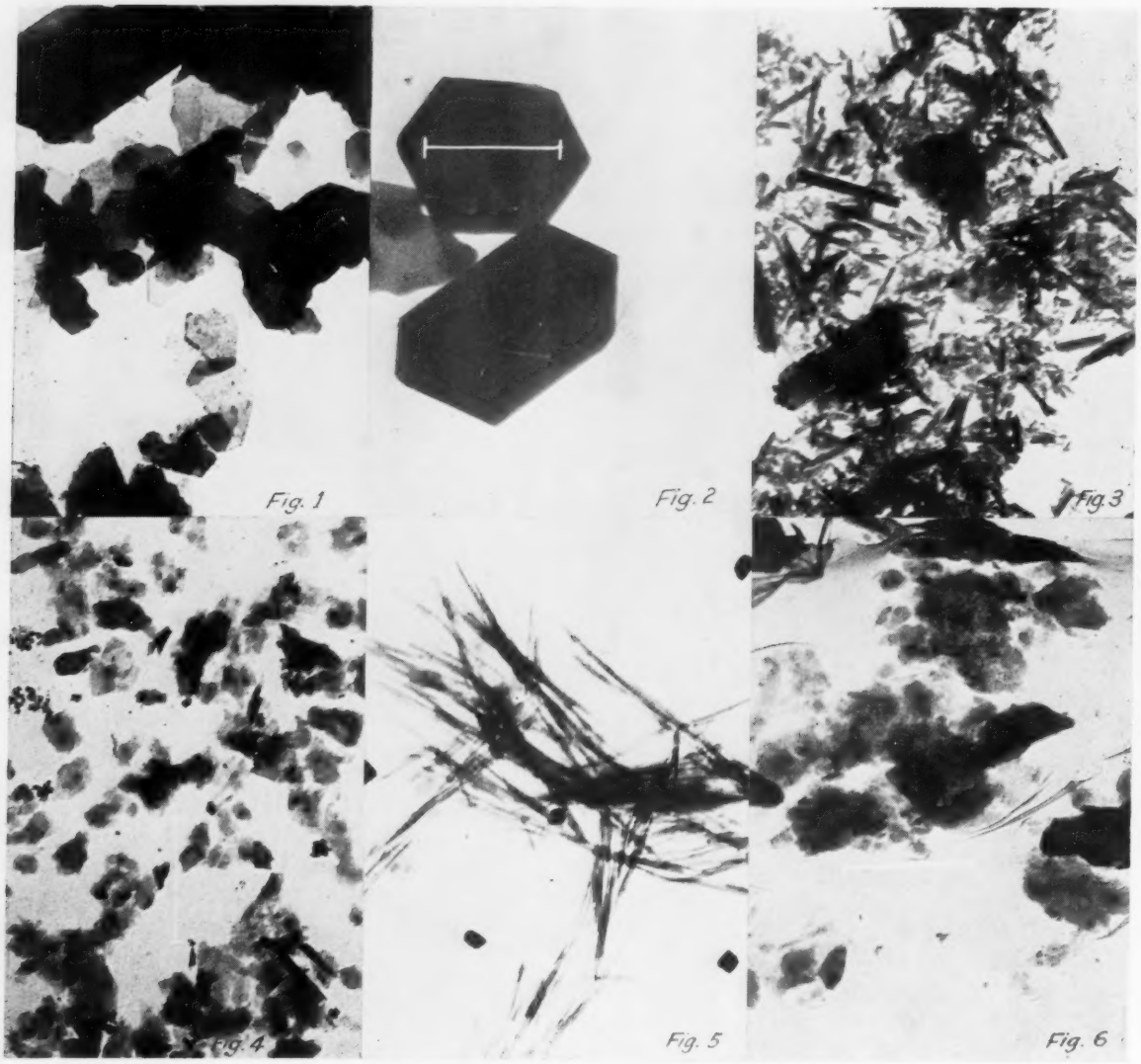

PLATE II
CLAY MINERALS OF THE 1:1 LATTICE TYPE
FIG. 1.—Kaolinite. FIG. 2.—Dickite. FIG. 3.—Halloysite
COMMERCIAL CLAYS
FIG. 4.—Sciotoville fire clay. FIG. 5.—Attapulgite. FIG. 6.—Ball clay.
(Unit of measurement, 1 μ.)

trict. The thin plate-shaped structures and the lack of mineral impurities explain its good plasticity, strong bonding power, and high refractoriness.

IV. General Discussion

Highly characteristic features in the crystal habit of the different minerals are associated with their chemical and physical properties. Wide variations in particle shape can be closely correlated with extreme differences in the behavior of clays. The structures exposed by electron microscope studies are of more value for purposes of correlation of the physical properties of unfired clay. With proper interpretation, however, electron photomicrographs will also provide a satisfactory understanding of such properties as plasticity, hydration, green strength, and shrinkage.

Plasticity results from (1) the interplay of the attractive force tending to hold the clay minerals together, (2) the thickness of the water film between the plates, and (3) the lubricating properties of the water film. Best working properties depend on the relative thickness of the water film to the strength of the force. As plasticity changes with structure variations, electron photomicrographs offer opportunity for valuable deductions from particle shape. In montmorillonite, the extreme thinness of plates and consequently the great number of water films indicate that the order of plasticity will be high. The extreme amount of surface area is also closely correlated with a

high bonding power and a high drying shrinkage. The structures of illite reveal quantities of surface intermediate in magnitude.

The hexagonal plates of kaolinite are stable. Their low base-exchange capacity is attributed to their stability and failure to develop an excess charge on the lattice through chemical replacements. The development of the crystals along the *c*-axis is emphasized by their opaqueness to the beam of electrons. The relatively low amount of surface per unit mass explains the low values for bond strength, drying shrinkage, and general plastic properties.

On hydration, a film of water envelops the exposed surface of the plates. Variations in amount and character of surfaces as exposed by the electron photomicrographs may explain the wide variations in swelling that exist among the different types of clay minerals. The extreme swelling and low chemical stability of magnesium bentonite is closely correlated with the fibrous structure of this clay mineral.

The firing characteristics of clays that are mixtures of clay minerals cannot be properly interpreted until the firing characteristics of the pure clay minerals have been studied. Figs. 4, 5, and 6 (Plate II) emphasize the significance of impurities.

It is impossible to resolve sufficient detail in electron photomicrographs to show ionic arrangements and the presence of alkalis and alkaline earths in quantities that render the clay nonrefractory. The resolving power, however, approaches this order of magnitude sufficiently close that those clays with an expanding lattice and a high exchange complex may now be characterized.

Tangible, pictorial evidence from electron photomicrographs on particle-size distribution, particle shape, and total surface area results in a recognition and a more complete understanding of the behavior of clay.

V. Summary

The electron microscope has been presented as a new tool for ceramic research.

Electron photomicrographs of montmorillonite, nontronite, illite, beidellite, hectorite, kaolinite, dickite, halloysite, and three commercial clays are presented. The montmorillonites show structures ranging from a fluffy, amorphous-appearing material to well-defined, extremely thin plates. A substitution of Fe for Al in the plate-shaped beidellite results in the lath-shaped structures of nontronite. Magnesium clays are fibrous in nature and emphasize the important correlation of crystal structure with chemical composition. Kaolinite and dickite are characterized by hexagonal plate-shaped crystals; the dickite crystals are considerably thicker. Halloysite is differentiated from kaolinite on the basis of its rod-shaped crystals. Electron photomicrographs of the three clays of commercial value emphasize the importance of mineral impurities.

With proper interpretation, electron photomicrographs will provide a satisfactory understanding of such properties as hydration, plasticity, green strength, and shrinkage. The quantitative correlation of chemistry with structures may offer a means for the rapid selection of raw materials for certain types of ware.

Acknowledgment

The author is indebted to A. F. Prebus for direction and assistance in the operation of the electron microscope and to C. E. Marshall and Wilber Stout for the use of clay minerals from their collections. The author has drawn freely on his joint studies with B. T. Shaw.

METHOD OF DETERMINING THE pH OF BALL CLAYS*

By George J. Barker and Emil Truog

The recent application of the base-exchange principle to structural clay products through pH control[1] has created interest in other ceramic fields where ball clays and casting slips are used. In attempts to apply the pH control to ball clays, difficulty has been encountered by the apparent inability to secure reliable pH readings when tests are made. The same ball clay, when tested by different users and when tested by the same person, often gives varying pH readings. It is quite obvious, therefore, that the conditions under which the test is made must be the governing factor controlling the pH. The purpose of this paper is to show how these varying results occur and to suggest two methods by which the correct pH values can be determined.

It has been shown, particularly by soils investigators, that the results obtained in pH determinations of soils and clays are influenced appreciably by the water-to-soil ratio that exists at the time the determinations are made. An increase in the ratio of water to soil invariably raises the pH values. This increase usually ranges from 0.1 pH to one whole pH unit and therefore is a matter of considerable concern.

Table I shows how the pH of five clays is increased by simply changing the quantity of water used to mix the clay. These five clays, two of which are kaolins and three ball clays, were prepared by mixing 20-gm. samples and adding water slowly from a burette to adjust the clay to a proper moisture content.

These various moisture contents were predetermined at critical points so as to obtain the following conditions: (1) complete granulation, (2) a plastic mass of high consistency (surface dull in appearance), (3) a plastic mass of medium consistency (surface shiny in appearance), (4) a plastic mass of low consistency which can be cast so that it assumes a smooth surface, (5) a fluid mass (a point at which the mass will flow of its own volition when hung vertically on a glass plate), (6) a soil-water ratio of 1 to 2.5, (7) a soil-water ratio of 1 to 5, (8) a soil-water ratio of 1 to 10, and (9) a soil-water ratio of 1 to 100. The pH was determined shortly after preparing the sample. The table clearly shows that (1) there is an increase in the pH

* Received August 13, 1942.

[1] (*a*) G. J. Barker and Emil Truog, "Improvement of Stiff-Mud Clays Through pH Control," *Jour. Amer. Ceram. Soc.*, **21** [9] 324–29 (1938); (*b*) "Factors Involved in Improvement of Clays Through pH Control," *ibid.*, **22** [9] 308–12 (1939); (*c*) "Further Investigations in the Improvement of Clays Through Control of pH and Character of Base-Exchange Saturation," *ibid.*, **24** [10] 317–22 (1941).

TABLE I

EFFECT OF DILUTION RATIO ON THE pH OF BALL CLAYS

Clay No.		Complete granulation	Plastic mass		Paste (Doughy)	Flow point	Soil-water ratio			
			Dull	Shiny			1:2.5	1:5	1:10	1:100
5	H_2O (%)	25	30	60	120	150				
	pH	4.97	4.87	5.10	5.30	5.30	5.48	5.48	5.50	5.90
6	H_2O (%)	30	40	70	90	120				
	pH	4.62	4.55	4.70	4.72	4.91	5.08	5.20	5.30	5.50
7	H_2O (%)	25	40	60	150	170				
	pH	4.45	4.49	4.55	4.88	4.92	5.09	5.09	5.27	5.93
8	H_2O (%)	40	50	80	170	200				
	pH	4.60	4.58	4.59	4.79	4.79	4.89	4.88	4.98	5.40
9	H_2O (%)	30	40	70	150	190				
	pH	3.97	3.80	3.91	4.12	4.29	4.30	4.39	4.49	4.85

TABLE II

Clay No. 5		Clay No. 6		Clay No. 7		Clay No. 8		Clay No. 9	
Time	pH	Time	pH	Time	pH	Time	pH	Time	pH
0 min.	3.70	0 min.	3.98	0 min.	4.65	0 min.	3.65	0 min.	3.22
1 "	3.91	1 "	4.03	3 "	4.55	1 "	3.70	1 "	3.22
2 "	4.16	2 "	4.11	5 "	4.58	2 "	3.73	2 "	3.22
3 "	4.28	3 "	4.18	10 "	4.68	4 "	3.75	3 "	3.18
4 "	4.34	4 "	4.26	15 "	4.68	5 "	3.80	4 "	3.18
5 "	4.35	5 "	4.38	30 "	4.68	10 "	3.90	5 "	3.05
10 "	4.50	10 "	4.54	*24 hr.	4.87	15 "	3.98	10 "	3.40
15 "	4.54	15 "	4.65			30 "	4.25	15 "	3.75
30 "	4.70	30 "	4.78			45 "	4.32	30 "	3.80
45 "	4.72	45 "	4.78			60 "	4.40	45 "	3.85
60 "	4.72	*24 hr.	4.60			75 "	4.45	60 "	3.90
*24 hr.	4.80					*24 hr.	4.63	*24 hr.	4.18

* Twenty-four hr. readings were taken after the samples were allowed to stand for 24 hr. after the completion of the shorter period; they were then mounted under an electrode, stirred for 5 min., and pH read.

value of the clay with increasing water dilutions and (2) the order of change of the pH is not regular and the change of increasing pH upon dilution cannot be predicted by comparing one clay with another. This table also probably explains why the soil chemist decided that it was necessary to establish a standard soil-to-water ratio of 1 to 2.5.

When pH was first used to study soils, 20 gm. of clay were used with 50 cc. of water; this same standard, therefore, was used to make the second series of tests. Table II shows the results of tests made on the same five clays when 20 gm. of clay were added to 50 cc. of distilled water and the mixture was stirred by hand until the clay was brought into suspension. The sample was then mounted under a glass electrode, and an electric stirrer slowly mixed the sample while the pH readings were taken over a period of time. The pH of the clay rises with increase of time, and this test indicates that time, as well as dilution, has some influence on the pH value of the clay. With these two variables affecting the pH reading, it is easy to see why the ceramist has difficulty in using the pH control for his clay. Because of the desirability of a standard procedure, considerable testing work was done in the Soils Department of the University of Wisconsin to investigate the reason for the variation in pH content. Many able writers have presented certain theories regarding the amorphous and crystalline structure of ceramic clays and the part which base exchange assumes when clays are treated for ceramic use. The information in the experiments so far

TABLE III

No.	Type of clay	Company	pH value
1	Champion and Challenger ball clay	H. C. Spinks Clay Co.	4.81
2	No. 5 ball clay	Cooley Clay Co.	5.00
3	" " " "	Kentucky Clay Mining Co.	4.06
4	Royal clay (Tenn.)	United Clay Mines Corp.	4.42
5	Ga. kaolin	Albion Kaolin Co.	4.95
6	N. C. kaolin	Harris Clay Co.	4.30
7	Old Mine No. 4 ball clay	Kentucky-Tennessee Clay Co.	5.15
8	Putnam clay (Fla.)	United Clay Mines Corp.	4.80
9	Gray ball clay	Bell Clay Co.	4.05
10	Tenn. No. 5 ball clay (air-floated)	Kentucky-Tennessee Clay Co.	5.32
11	No. 12 ball clay (disintegrated)	" " " "	4.80
12	P. L. No. 1 English china clay	Moore & Munger	6.50
13	E.P.K. Fla. kaolin	Edgar Plastic Kaolin Co.	6.64
14	Harris Lunday kaolin	Harris Clay Co.	5.60
15	Dresden ball clay	Bell Clay Co.	4.98
16	Victoria clay (Tenn.)	United Clay Mines Corp.	4.71
17	Dark ball clay	Bell Clay Co.	4.81
18	Wade No. 5 ball clay (air-floated)	Kentucky-Tennessee Clay Co.	4.83
19	No. 90 English ball clay	Paper Makers Importing Co.	5.83

conducted is not entirely in accord with all of the theories advanced. The writers will not go into the theory of the question, therefore, until further experiments in our laboratories have been completed. Instead, two methods by which reproducible pH's can be secured by any operator testing kaolins and ball clays will be described.

Method No. 1: Place 20 gm. of clay screened to pass a 20-mesh sieve on a smooth glass plate. Carefully add 20 cc. of water. Work this water thoroughly into the clay with a spatula until a bright shiny surface is obtained. Add additional water to the clay and thoroughly work in with a spatula until the mass becomes too soft to stay on the glass plate. Transfer the clay to a beaker and add the remaining water necessary to constitute a total of 50 cc. Stir the mixture with a glass rod until it is evenly mixed and then determine the pH with a glass electrode. A clay sample thus prepared will give a maximum pH which can be checked accurately by repeating the performance.

Method No. 2: Add 20 gm. of clay which has passed a 20-mesh sieve to 50 cc. of water in a beaker. Stir the mixture violently with an electric propeller (such as is used in a malted-milk mixer) for 15 min. and then determine the pH of the clay with the glass electrode. This method is accurate and is the method recommended for use in our laboratories.

Three minerals generally are accepted to be in the greater proportion of clay samples, viz., kaolin, illite, and montmorillonite. These clay minerals will take water in the following order: kaolin, slowly; illite, slightly more rapidly but still slowly; and montmorillonite, rapidly. If the clay is composed mainly of montmorillonite, the maximum pH values may be reached, therefore, with comparative ease in a few moments of mixing. Illite will attain a maximum pH value in a slightly longer mixing period. Kaolin, however, will require considerable working to reach the highest pH value. The clays which have higher base-exchange capacities obtain stability readily; those of low base-exchange capacity require considerable working to reach stability. It is not necessary, therefore, to mix all clays for 15 min. Successive pH readings should be made until a constant value is obtained. For accurate results, a high-speed disperser must be used to accomplish, in a reasonable time, the complete wetting of the clay which is necessary to give a constant pH.

Table III shows the pH value of nineteen clays commonly used in the ceramic industry.*

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* Clay samples submitted by J. H. Koenig, Hall China Co., East Liverpool, Ohio.

Discussion

W. Schoeninger: What was the method of preparing samples where you noticed the increase in pH over long periods? Was that different from the 15-minute mixing that achieved your true pH?

G. J. Barker: Yes, in that method we put the clay into the beaker and stirred it with a glass rod by hand. There was considerable stirring action, but it was not violent enough to bring the pH to its true value. Stirring with a glass rod will not bring it to its true value.

As I stated before, there are generally three classes of minerals in clays: kaolin, illite, and montmorillonite. Ball clays that have relatively small quantities of each one of these will establish a true pH very quickly. In the structural clay product clays, the pH can be raised by stirring with a glass rod because there is no appreciable quantity of kaolin in those clays. Illite will come up rather rapidly, but kaolin will not; such clays take a longer working period.

Edward Schramm: Is the final pH affected by the initial pH in the water?

G. J. Barker: In our tests, we found that if distilled water is used it is not affected, and we have used distilled water in our experiments. When we used CO_2 or ammonia with distilled water, we found a little change. When using the distilled water, the pH was 6.2 or 6.3.

O. C. Ralston: What do you mean by a "true kaolin" on which you have obtained pH measurements? Do you mean a kaolin whose base is complex or one that is saturated with hydrogen?

G. J. Barker: I mean a true kaolin which has no base exchange, if such a thing is possible. Dr. Johnson, is it possible to have about 1 milliequivalent?

A. L. Johnson: Yes, it is possible to have an exchange capacity of 1 m.e. for a sample of kaolinite. Such a low exchange capacity would result, providing the sample contains particles sufficiently coarse so that the total surface area is small. This is true because the exchange capacity is related to the surface area of kaolinite. In the paper in which we discussed the pH of a purified kaolinite suspension that approaches a value of 7, we were referring to the hydrogen form; that is, the kaolinite suspension would tend to approach that of the water used. Superconductivity water has a theoretical pH value of 7. Conductivity water at such a pH, however, is difficult to obtain and practically, the value is in the range of 6.3 to 6.7. If such water were used with a purified kaolinite, therefore, I would not expect clay whose exchangeable ions were hydrogen to alter that value appreciably. The value as such is not the important point. The important point lies in the fact that if hydrogen occupies the exchange positions in kaolinite, the pH of the clay suspension would approach that of the water used.

K. C. McCartt: Professor Barker, have you considered the possibility of the loss of CO_2? In our plant, we mix a 10-lb. sample of clay with a ratio of $2^1/_2$ parts of distilled water to 1 part of clay in a mechanical mixer overnight, and we are able to reproduce pH by that method. It is a closed system. There is no possibility for CO_2 to escape. I have noticed that if the sample is permitted to remain in a beaker, there will be an increase of pH.

G. J. Barker: We have worked in the laboratory with distilled water, and in checking that question carefully we find that the water will absorb CO_2 from the atmosphere. We have also carried out experiments where the water has been thoroughly boiled and the CO_2 removed; tests have been made with it. I doubt very much whether the CO_2 is lost from the sample. In your case, you might be using one of those clays that will come to equilibrium rather rapidly. On the 19 clays tested, we have clays that we can bring to stable equilibrium pH possibly in as little as 2 minutes stirring time. So by mixing thoroughly and letting stand overnight, you probably have found a way that will give a reproducible pH.

R. E. Jordan, Jr.: What is the practical application of the knowledge of pH in connection with dust-pressed operations; for example, is there any practical application of pH of clay in making tile bodies?

G. J. Barker: I do not know what type of clay you are using in your dry-pressed product. If your clay has base-exchange capacity, then I believe the pH of the clay would be of value to you.

SOLUBLE CONSTITUENTS*

By K. C. McCartt

A few years ago, certain soluble constituents of raw materials, particularly clays, were determined in an attempt to find at least a partial answer to the unexplained variations in casting conditions in making sanitary ware. At the same time, a system of much closer control over slip preparation and raw-material specifications was instituted. That this program has been of value is evidenced by the fact that the percentage of off-grade ware has decreased markedly.

The solubles determined are chlorides, sulfates, and calcium and magnesium and their acidity and alkalinity characteristics. For the tests, samples are taken at several points on the working face as a car of raw material is unloaded. These samples are mixed thoroughly, and the 10-lb. sample (dry basis) used for analysis is made into a slip with 25 lb. of distilled water. A portion of the filtrate is then taken while the slip is being dewatered in a small filter press. The acidity characteristics are determined on a sample of the slip after it passes through a 60-mesh screen.

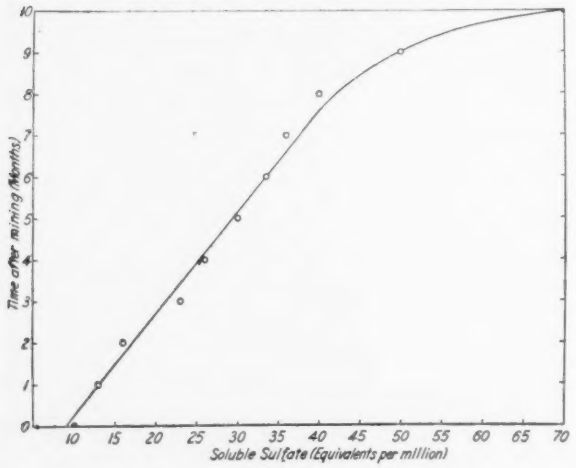

FIG. 1.

The concentrations of the various solubles determined are calculated from the analyses as equivalents per million in terms of dry material.

The chloride determination is made by the Mohr[1] method in which the chloride is determined volumetrically by titrating with silver nitrate solution; potassium chromate is used as the indicator. This determination is used chiefly for (1) checking English china clay for sea-water contamination and (2) as a check for wash-water contamination in washed American clays.

The sulfate determination is made by titrating with barium chloride solution; tetrahydroxyquinone[2] is used as the indicator. This, together with the determination of acidity characteristics, is one of the most valuable tests. If records are kept for a sufficient length of time, the length of time that has elapsed and the amount of oxidation that has taken place after the clay was mined may be estimated on certain American ball clays (see Fig. 1). This is important, because a ball clay which has been mined and stored for a few months produces a casting slip with markedly different characteristics than a slip prepared from freshly mined clay. For example, slip prepared from freshly mined ball clay (1) ages much more rapidly than a slip made with older clay, (2) is more plastic, and (3) screens more readily. It does not press so well, however, as a slip containing older clay. Such findings are based on actual plant operation over a considerable period of time.

The sum of the calcium and magnesium in soluble form is determined by the A.P.H.A. soap-hardness method, which is used principally to indicate (1) the nature of the ground water in the clay bed and (2) the amount of exchangeable calcium and magnesium in the clay. For example, a clay which shows a high soap-hardness reading will usually require a greater amount of deflocculant than a clay of the same type with a lower reading, if other variables remain the same.

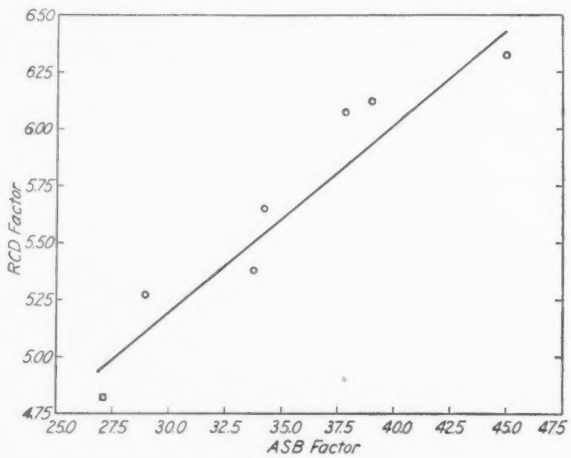

FIG. 2.

For the acidity determination, a weighed sample of slip and all reagents used are cooled to 5° to 10°C., 10 ml. of 10% sodium chloride solution is added, and sufficient 0.01 *N* sodium carbonate solution is added to produce a pH higher than 8.5, as measured by a glass electrode electrometer. The mixture is titrated with 0.01 *N* hydrochloric acid solution to a pH of 8.5 and then to a pH of 4.5; both readings are recorded. (This method is an adaptation of the Warder method[3] for the determination of mixed alkali carbonate and bicarbonate.) A blank run is made, and the original readings are corrected. From these

* Received April 23, 1942.

[1] F. P. Treadwell and W. T. Hall, Analytical Chemistry, 7th ed., p. 604, II. John Wiley & Sons, Inc., New York, N. Y.

[2] R. T. Sheen and H. L. Kahler, "Direct Titration of Sulfates; Further Studies with Tetrahydroxyquinone as an Internal Indicator," *Ind. Eng. Chem., Anal. Ed.*, **8** [2] 127–30 (1936); *Ceram. Abs.*, **15** [8] 258 (1936).

[3] F. P. Treadwell and W. T. Hall, *loc. cit.*, p. 488A.

figures, the amount of strong and weak acid (or weak acid and base) in the clay can be calculated. Any acidity characteristic, either (1) the presence of free inorganic acid or organic acid (it is quite possible in ball clays that the free acids are organic acids to some extent) or (2) adsorption on the clay particle, which will react with both sodium atoms in the sodium carbonate is considered to be a strong acid. Any acidity characteristic which will only react with one sodium atom to produce bicarbonate is considered to be a weak acid. Conversely, any alkalinity characteristic which will react similarly to alkali bicarbonate in neutralizing 0.01 *N* HCl is considered to be a weak base. If it reacts similarly to sodium carbonate or any stronger base, it is considered to be a strong base.

The effect of the sulfate acidity and alkalinity characteristics of the raw materials on the preparation of a casting slip is shown by the curve in Fig. 2, which was prepared from the statistical analysis of sliphouse records over a period of a year. The RCD factor is the product of the weight in grams of a rate of cast cup (30-min. cast) times the weight of deflocculant per blunger (in lb.) times 0.133/sp. gr. -1.667×10^{-3}.

More simply, it is a measure of the amount of deflocculant necessary to produce a definite rate of cast at a definite slip specific gravity. The ASB factor is the sum of the strong acid plus sulfate minus total base expressed as equivalents per million in terms of the dry batch weight. Although the relation is not exact, it does indicate that there is a definite relation between the solubles in the raw materials and the behavior of such raw materials when made into casting slip.

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MINERALOGICAL AND RATIONAL ANALYSIS OF BALL CLAYS*

By T. N. McVay

Although there has been an enormous amount of research on minerals present in clays, particularly the kaolins, little has been done with ball clays. All clays are difficult to examine petrographically, but this is particularly true of ball clays, as they are exceptionally fine grained and contain organic material which makes the optical examination of the minerals present more difficult.

According to Grim and Bray,[1] who have been studying fine-grained clay sediments for a number of years, a representative ball clay from the Kentucky district consists principally of kaolinite, from 10 to 15% each of illite and quartz, and a small amount of montmorillonite. Studies of ball clays by X-ray diffraction methods have also shown that they consist primarily of kaolinite. Except for the work of Grim and Bray[1] and Grim,[2] the literature does not contain any critical study of the fine clay fractions present in ball clays. The writer has examined the accessory minerals present in such clays and finds quartz to be the most common. Other minerals, such as zircon, rutile, mica, and tourmaline, are frequently present, and microcline feldspar has been noted in some of the English ball clays. The total amount of accessory minerals in ball clays varies greatly (this is especially true of quartz). The grain size of the accessory minerals also shows marked differences in different ball clays.

According to Grim, clay minerals found in sediments may be classified according to Table I.

As (1) anauxite and kaolinite are the end members of an isomorphous series, (2) montmorillonite contains bases such as the alkalis and alkaline earths, and (3) illite is probably an isomorphous series of minerals rather than an individual, it is impossible to calculate a satisfactory rational analysis of a ball clay from the ultimate analysis. A further complication arises because the alkalis cannot be distributed properly, as they may be present in the same clay as exchangeable bases or in the minerals illite, montmorillonite, muscovite mica, or feldspar. The proper distribution of the iron and alkaline earths is also difficult.

Table I

Name	Chemical composition	Remarks
Kaolinite	$Al_2O_3\cdot2SiO_2\cdot2H_2O$	Anauxite and kaolinite form an isomorphous series
Anauxite	$Al_2O_3\cdot3SiO_2\cdot2H_2O$	
Halloysite	$Al_2O_3\cdot2SiO_2\cdot xH_2O$	
Beidellite	$*Al_2O_3\cdot3SiO_2\cdot xH_2O$	Beidellite and nontronite form an isomorphous series
Nontronite	$*Fe_2O_3\cdot3SiO_2\cdot xH_2O$	
Montmorillonite	$*Al_2O_3\cdot4SiO_2\cdot xH_2O$	Montmorillonite, beidellite, and nontronite probably contain essential alkalis or alkaline earths
Illite	$(OH)_4Ky(Al_4\cdot Fe_4\cdot Mg_4\cdot Mg_6)(Si_{8-y}\cdot Al_y)O_{20}$ (When *y* equals 2 and magnesium and iron are absent, this is the formula for muscovite)	

* These formulas are to be considered tentative pending further researches.

With the older methods of calculation, the alkalis and the lime were allocated to feldspar, the remaining alumina was allocated to theoretical kaolinite, and the remaining silica was considered to be quartz. This is obviously incorrect, as feldspars are an infrequent constituent of ball clays.

The older chemical methods of rational analysis for the separation of minerals in clays have never been satisfactory. Rational analyses have, therefore, been calculated from the ultimate analysis, which can be very accurate.

Undoubtedly the methods developed by Grim and others could be used, but they require a highly skilled technique and are time-consuming.

The following procedure is suggested as a basis for comparing different ball clays:

Allocate all of the alumina to kaolinite with the formula $Al_2O_3\cdot2SiO_2\cdot2H_2O$ and regard any silica not required by the formula as excess rather than free silica, for silica in excess of that amount is needed to take care of all of the alumina as kaolinite. Report the total alkalis, the total alkaline earths, and the iron separately. The titanium may be considered to be rutile, although ilmenite may be present.

* Received April 23, 1942.

[1] R. E. Grim and R. H. Bray, "Mineral Constitution of Various Ceramic Clays," *Jour. Amer. Ceram. Soc.*, **19** [11] 307–15 (1936).

[2] R. E. Grim, "Relation of Composition to Properties of Clays," *ibid.*, **22** [5] 141–51 (1939).

This is only an approximate rational analysis, but it should serve to compare various clays of the same type.

As examples of this procedure, the analyses of three clays taken at random are given as follows:

ULTIMATE ANALYSIS

	No. 1 S.G.P. ball clay (%)	No. 11 ball clay (%)	1X wad clay (%)
SiO_2	47.0	50.67	62.72
Al_2O_3	37.83	32.54	24.34
TiO_2	1.20	1.47	1.60
Fe_2O_3	0.71	0.89	1.14
CaO	Trace	0.65	0.40
MgO	0.20	0.41	0.58
K_2O	0.10	1.20	0.75
Na_2O	0.42	0.52	0.61
Ignition loss	12.50	11.75	7.46
	99.96	100.10	99.60

RATIONAL ANALYSIS

	No. 1 S.G.P. ball clay (%)	No. 11 ball clay (%)	1X wad clay (%)
Kaolinite	96.0	82.4	61.6
Excess silica	2.5	12.4	33.1
Rutile	1.2	1.5	1.6
Fe_2O_3	0.7	0.9	1.1
Alkaline earths	0.2	1.0	1.0
Alkalis	0.4	1.7	1.4
	101.0	99.9	99.8

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WATER OF PLASTICITY*

BY J. W. WHITTEMORE

Close control in the various steps of manufacture has resulted in savings for the ceramic industry. Previous high losses in drying and firing have been reduced in many cases by control over clayware-forming conditions. Increased knowledge of the reasons for forming losses or subsequent failure of the products in some later step of the production has increased interest in the control of water of plasticity. Water of plasticity is closely related to many of the other properties of a clay product such as (1) ease of forming, (2) ease of drying, (3) drying shrinkage, and (4) firing shrinkage.

Any discussion of the expression "water of plasticity" or the establishment of a means for quantitatively determining its value requires an agreement on the meaning of the phrase. Water of plasticity implies an amount of water required to develop the plastic properties of a clay. Within this statement there are two elements, viz., (1) an amount of water and (2) plasticity. It is the second element that causes difficulty in arriving at any method for measuring this property of a plastic clay mass.

"Plasticity" is that property of a clay-water mixture which enables it to be deformed into a desired shape by the application of a force which exceeds the yield value of the mixture and to retain that shape after the deforming force is removed. The maximum degree of plasticity is developed in a clay when each grain is entirely surrounded by a film of water. This maximum plasticity for any particular clay mass will be affected by (1) occluded air or gases, (2) additions of electrolytes, (3) any additions which will affect the viscosity of the water film, and (4) other factors which will disturb the charge of the particle and the water. Variations in the amount of pugging will affect the plasticity principally by affecting the distribution of the water with the clay grains and by the introduction or removal of air. Variations in the amount of water added to the clay also will affect the degree of plasticity.

Excessive amounts of water will cause loss of plasticity and stickiness or fluidity. Insufficient water will cause the mass to crumble and fail to exhibit plastic properties. There is a range of plasticity within these limits with corresponding variations in the amount of water present. With some clays this range or variation of plastic condition or degree of plasticity will have a corresponding definite amount of water.

When a clay mass has been made plastic and formed into a shape, the amount of water included within the piece can be determined easily. It is difficult, however, for the same person to obtain the same degree of plasticity again, even though the same clay and apparently the same treatment are used, and it is almost impossible for another person to reproduce the same treatment and plastic condition. The personal factor therefore plays an important part in any method for the treatment of water of plasticity.

The methods recommended by The American Ceramic Society[1] and the Tentative Method of Test for Liquid Limit of Soils (D423–38T) of the American Society for Testing Materials are probably the most commonly used for determining the amount of water of plasticity. The A.S.T.M. method is intended as a method for measuring the liquid limit of soils, but it can be used to measure the plastic condition and the corresponding water content. It is similar to the method for determining the upper limit in the Atterberg method for measuring plasticity.[2] Each method has its limitations and is affected by the personal factor.

American Ceramic Society Method

The clay is ground to pass a standard No. 20 sieve, and after thorough wedging and kneading the plastic clay is forced into a mold $1^1/_8$ in. square; specimens $1^7/_8$ in. long are then cut from the clay. As an alternate method of forming, the plastic clay may be extruded by a piston plunger press and cut to the $1^7/_8$-in. length. Immediately after forming, the samples are marked for identification and weighed. After drying to constant weight, the specimens are again weighed and the water of plasticity is ex-

* Received April 23, 1942.

[1] "Standards Report," *Jour. Amer. Ceram. Soc.*, **11** [6] 449–50 (1928).

[2] Heinrich Ries, Clays, Their Occurrence, Properties, and Uses, pp 189–90. John Wiley & Sons, Inc., New York, N. Y., 1927; *Ceram. Abs.*, **6** [10] 485 (1927).

pressed as the weight of water in percentage of the dry weight of clay.

The inaccuracies or variations in results obtained with this method lie entirely within the preparation of the clay and the forming of the samples. Much of this variation could be removed if the clay, after screening, were pugged in a laboratory grinding pan under vacuum for a definite length of time and if the samples were always formed by a piston plunger press under vacuum. When the clay is pugged and formed by hand, the personal factor will introduce many possible variations.

American Society for Testing Materials Method

After grinding to pass a No. 40 sieve, 100 gm. of the material are thoroughly mixed with distilled water until the mass becomes a thick paste. This paste is then shaped into a thin layer 1 cm. thick at the center of a mechanical apparatus which has a brass container for the clay similar in shape to a watch glass. The smoothed paste is divided through the center with a special grooving tool, and the container is bumped mechanically until the groove is closed. For soils, the soil-water ratio is adjusted until a consistency is found which will just close the groove with 25 bumps applied at the rate of 2 bumps per sec. The sample is then dried at 110°C. to constant weight, and the liquid limit is expressed as the weight of water in percentage of the dry soil.

The equipment used in this method is comparatively inexpensive. Most of the steps are mechanical and reduce the effect of the personal factor. Mixing the material with the water and placing the material in the container are not mechanical, however, so possible variations and inaccuracies owing to the personal factor are still introduced.

Either method could be improved by (1) including more mechanical steps or (2) including a more exact procedure for preparing the test specimen. Either method could then be used satisfactorily to determine the water of plasticity of a clayey body or the effect on water of plasticity of the replacement of one ball clay by another in a body.

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PLASTICITY AND WORKABILITY OF BALL CLAYS*

BY E. C. HENRY

ABSTRACT

Methods for measuring the flow properties of ball clays in the plastic state are compared. The concepts of "workability" of interest to ceramists include (1) plastic flow properties (yield value and mobility), (2) adhesiveness (stickiness), and (3) cohesiveness (the ability to be deformed without rupturing). Ball clays probably influence the workability of a whiteware body chiefly by making it cohesive.

I. Introduction

Clay workers have long been interested in plasticity, by far the most important property of clay, without which it would be of comparatively little value for the manufacture of ceramic products. Ries[1] defines plasticity as the property which many bodies possess of changing form under pressure without rupturing, which form they retain when the pressure ceases. It is understood that the amount of pressure required and the degree of deformation possible will vary with the material.

It is generally agreed that the word "plasticity" should be applied only to the true physical property which enables a material to be deformed continuously and permanently by the application of a stress which exceeds a critical value (yield stress) of the material. A more appropriate term to describe the more complex property in which workers in the clay industries are interested and which includes the factor "without rupturing" in the definition by Ries, would seem to be "workability" as used, for example, by Graham and Sullivan.[2]

The methods which have been used in the past few years for measuring the flow properties of ball clays in the plastic state are summarized in the following paragraphs. It is assumed that no reference will be necessary to older, more familiar apparatus or tests such as the Bingham-Green plastometer, the Emley plasticimeter, or the Stringer and Emory ball deformation test.

* Received June 27, 1942.

II. Comparison of Test Methods

The devices for measuring the plasticity or workability of clays generally fall in one of three groups, viz., (1) those which measure the yield value and mobility of the clay (stress-strain relations) by subjecting the test piece to torsion, (2) those which measure these properties by compression, and (3) those which do not measure the flow properties as such, but which compare the energy transmission or the cohesiveness of the material being tested.

(1) Methods Based on Torsion

The plasticity of finely ground minerals with water was studied by Wilson,[3] who used a torsion apparatus to obtain stress-strain diagrams. This method was used also by Norton[4] and by Graham and Sullivan.[5] The chief advantages claimed for this type of apparatus are its sensitivity, its rigidity, and the reproducibility of results. It seems to be an excellent machine for research, although it may be too slow for practical testing because of the great care needed to produce test bars.

(2) Methods Based on Compression

Whittemore[6] describes an apparatus in which a stainless-steel hemisphere is forced into plastic material, the distance of penetration with time following the relationship $d = at^P$. The exponent, P, is considered to be an index of the plasticity of the clay. The apparatus is sensitive to any change in the treatment of the material, such as de-

airing, the addition of electrolyte, or aging, but the operator must have considerable experience to obtain satisfactory results.

Roller's apparatus[7] applies a steadily increasing vertical stress to a clay cylinder between parallel plates and records the resulting deformation. The relation between the height of the cylinder at any time, the pressure being applied, the yield pressure, and the original height is expressed by the equation $p = p_0(h/h_0)^k$. The constant, k, is called the coefficient of renitence (resistance) and is considered to be an inverse quantitative measure of plasticity. The Roller method of preparing test pieces may not assure sufficient uniformity in some instances.

Russell and Hanks[8] used a clay-compression apparatus in which cylindrical specimens were squeezed between parallel plates at a constant rate of strain. This apparatus probably simulates the stress conditions which exist in the molding of plastic clay bodies better than the torsion apparatus. Essentially true values of stress and strain are obtained; the apparatus is flexible and gives reproducible results. It is sensitive to small changes in plastic properties but as designed it is somewhat too complicated for rapid routine plant tests.

Thiemecke[9] describes a compression-deformation method for determining the water content at which a plastic clay body changes to an elastic condition. The transition point for an earthenware body is at approximately 12.8% water and coincides closely with the water content at which the drying shrinkage of the body is practically complete. In the plastic range, correlations were found between water content and yield value, deformation per unit stress beyond the yield value pressure, total deformation at ultimate pressure, and the pressure necessary to cause ultimate failure of the cylindrical test piece.

Stull and Johnson,[10] who investigated the relationship between moisture content and flow-point pressure, forced plastic material through a die by means of a cylinder and a mechanically driven piston. This is somewhat similar to the principle of the Bingham-Green plastometer.

(3) Methods Based on Cohesiveness

Thiess[11] and McVay[12] show the possible value of the Brabender Plastograph for determining the plastic properties of porcelain bodies and clay. This instrument records the consistency of clays at various water contents and shows differences between clays. It does not require the preparation of a test piece, but more experience seems to be necessary before the interpretation of the results will be entirely satisfactory in predicting ceramic behavior.

(4) The Body Tester

Endell[13] describes a "body tester" which combines compression and torsion and closely simulates industrial jiggering practice. An Endell-type tester, built in the instrument shop of the School of Mineral Industries at the Pennsylvania State College and improved by the writer and several of his students,[14] automatically squeezes a cylinder of plastic clay or body about $1^1/_2$ in. in diameter and 2 in. high with a gradually increasing force and at the same time subjects the test piece to a slight torsion. Provision is made for continuously recording the pressure applied and the resulting deformation, and the appearance of cracks on the surface of the cylinder shows the operator the limit of workability of the sample. This apparatus combines the measurement of flow properties and cohesiveness. Experience at a number of ceramic plants producing ware by various methods over a wide range of consistencies indicates that if bodies of equal firmness are compared, the body capable of undergoing the greater deformation before rupture should be the more workable. Disadvantages of this apparatus are as follows: (1) the stress application is complex, so that true values of stress and strain are not obtained, and (2) the present model is not sensitive enough, at most consistencies, to show the yield value.

With any of these instruments except the Brabender Plastograph, the preparation of test pieces is important. Nearly all of the investigators have recognized erratic results caused particularly by entrapped air and laminations.

III. Role of Ball Clays in Plastic Bodies

Russell and Hanks[8] point out that any practical consideration of the plastic molding properties of a ceramic clay or body involves the capacity to (1) be worked and shaped to the desired form in a reasonable time and with moderate pressure, (2) withstand considerable deformation during working and forming without rupture, (3) be removed from the mold or forming device without sticking, and (4) retain the formed shape against the action of gravity and inertia forces of handling. Factors (1) and (4) depend largely on the mobility and yield value of the body, whereas factors (2) and (3) depend on the cohesiveness and adhesiveness of the material. All four factors, however, are involved in the plant man's concept of workability. The consistency and yield value of a whiteware body are influenced greatly by the solid-water ratio, whereas cohesiveness and adhesiveness depend largely on the amount and kind of ball clay.

More attention, therefore, might be given to measurements of the contributions of the various ball clays to the workability of whiteware bodies and in particular to the ability to be deformed without rupture. It might be worth while, for example, to determine the amount of deformation possible before failure, when different ball clays are substituted for each other in a series of standard bodies and are subjected to a standardized stress procedure.

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Discussion

D. E. Postlewaite: Can these techniques be successfully applied to casting and do you get any more information on these types of tests?

E. C. Henry: We were able to predict the behavior of a casting slip by testing samples cut from the plastic filter-press cake. Measurements made on test pieces cast from a body might show how far the body could be deformed (when the pieces are being fit together or being finished) without danger of cracking.

Chairman Russell: The paper presented by Dr. Henry shows how complicated an evaluation of plastic properties is. At the present time, we do not know how the plastic properties of ball clays should be evaluated. There are various methods available for use, and we shall probably attempt to determine the plastic character of the different ball clays by a number of different methods and compare them.

EVALUATION OF PLASTIC PROPERTIES OF CLAY MASSES*

By Ralston Russell, Jr.

Abstract

The factors involved in the evaluation of plastic properties of clay masses are discussed. Some of the commonly used methods of testing the plastic character of clays are described, and several adaptions of tests often used on clays are proposed for consideration.

I. Introduction

One of the primary reasons for the use of clays in whiteware bodies is their plastic behavior. Although it is generally recognized that each clay has its own peculiar plastic characteristics, no completely satisfactory method of definition or evaluation has ever been evolved.

The difficulty of evaluation is readily appreciated when one considers the numerous theories which have been advanced to account for the plasticity of clays and also that plasticity involves several widely different characteristics, such as, for example, workability and cohesiveness. Watts[1] has described two types of plasticity, viz., (1) greasiness or lubrication and (2) stickiness or bonding power. The nomenclature used to describe plastic properties is not important, but full recognition should be given to the fact that plasticity as associated with clays involves several characteristics, none of which can be overlooked in a complete evaluation.

Many different methods have been used to study the plastic behavior of clays and to permit an evaluation. Some methods are largely theoretical, with an attempt to obtain absolute understanding and analysis; others, however, are merely practical methods of obtaining comparative results. Whatever the merits or deficiencies of any individual method, it seems safe to predict that a really satisfactory evaluation of clays on the basis of their plastic properties will take into consideration the different controlling factors involved and thus permit a composite analysis. This may mean an analysis based on several widely different tests in the determination of the true plastic character of a particular material, with simple, comparative, modified methods being used for plant control.

Some of the most recently developed methods involving the use of rather special equipment will be described in another paper. The following discussion therefore deals largely with the simpler as well as some of the older methods.

II. Miscellaneous Methods of Evaluation

(1) Viscosity Tests

Comparative viscosity tests have been used to indicate plasticity. Such tests involve the determination of viscosity-water content relationships. Any standard method of measurement may be used, such as the Mariotte tube viscosimeter, the Gardner mobilometer, the Stormer viscosimeter, the MacMichael viscosimeter, or the Irwin consistometer. Such a measure of plasticity is affected by the presence of soluble electrolytes, which influence viscosity. The determination, moreover, of plasticity on liquid slips rather than on plastic masses is of limited value.

The Bingham-Green plastometer[2] is a refined modification of the flow-type viscosimeter which has been used to measure yield value and mobility of clay suspensions and which has also been modified to study masses of plastic consistency. This apparatus is elaborate and has not found widespread application in the evaluation of the plastic properties of clays.

* Received April 23, 1942.

(2) Extrusion and Plastic Flow

(*a*) Atterberg plasticity number: Atterberg developed a fairly simple method of classifying clays.[3] He added water to obtain five different conditions, as follows: (1) the upper limit of fluidity, or the point where the slip flows as water, (2) the lower limit of fluidity where two portions of clay will just flow together when the container is rapped, (3) normal consistency or the sticky limit where the clay is most workable and will no longer stick or adhere to metal, (4) the rolling limit where the clay can no longer be rolled into "threads," and (5) the condition where the clay will no longer hold together when subjected to pressure. Atterberg assumes that plasticity is defined by the range in water content of a workable body and the greater the difference between the water contents of the lower flow limit (2) and the rolling limit (4) the greater the plasticity.

This method does not distinguish satisfactorily between different types of clays and is quite dependent upon the personal element. It is, however, simple and fairly indicative for comparisons.

(*b*) Column extrusion: Watts[4] has extruded plastic clay vertically through a straight walled die of fixed thickness under constant pressure and has determined the weight of the wet bar which can be extruded without parting because of its own weight. In this test, the water is added in an amount assigned by Atterberg No. 2, or the lower limit of flow.

Bleininger and Ross[5] and Stull and Johnson[6] have studied the relationship between moisture content and the flow of clays through dies under pressure and all have found a hyperbolic relationship. Stull and Johnson have devised a formula for this relationship. These methods depend essentially upon the pressure required to cause extrusion of a column of plastic clay, and by these methods small changes in moisture content are reflected in definite changes in the flow-point pressure. Such a test offers a practical means of evaluation of those plastic properties related to flow under pressure and might be adapted to broader interpretation.

(*c*) A method of determining the greasiness or plastic flow value is suggested by Watts.[7] Water is added to the clay in an amount to attain Atterberg No. 2. This clay-water mixture is spread on a flat-faced power whirler to a fixed depth, and a jigger shoe with a 1-in. face and 5-degree slope is gradually brought into contact. The amount of power in amperes required to maintain 100 r.p.m. is the value of plastic flow.

(3) Cohesiveness and Stickiness

(*a*) Sortwell[8] in his study of ball clays determined the cohesiveness of plastic clay. A metal receptacle was filled with plastic clay to yield a flat surface. A flat glass disk suspended from one arm of a torsion balance was then slid into position in such a manner that the entire surface was in contact with the clay. Shot was then allowed to run into a cup suspended from the other arm of the balance until the weight was sufficient to cause the plastic clay to pull apart. The adhesion of clay to glass and metal was greater than the cohesion of the clay in all cases. Cohesion values were obtained over a range of water contents and decreased with increase in water content. Those clays with a higher value for cohesion at a given water content work better in following a jiggering tool and have less tendency to break.

This test might be improved by substituting a hemisphere or inverted cone for the flat glass disk.

(*b*) A stickiness test for clays was developed by Olmstead.[9] The apparatus consists of a polished steel roller 20 cm. long and 5 cm. in circumference and a movable brass plate which slides under the roller with a clearance of about 4 mm. A 15- to 20-gm. clay sample is mixed with water, placed on the plate, and then fed against the roller which is rotated in a direction to force the clay underneath it. The "sticky point" is attained when the clay barely fails to adhere to the roller at a shearing speed of 5 cm. per sec. The moisture content is then determined.

This method of test is more reliable and impersonal than any other dynamic test available. For static tests, Olmstead recommends some type of standardized glass plate test which depends upon adhesion to a flat surface. Many other stickiness tests, such as adherence to the finger, spatula, or walls of a mixing machine, have been used, but according to Olmstead none of these appears as promising as the roller test.

(4) Deformation by Pressure

(*a*) The oldest and most widely used method of evaluation of plastic properties is the "hand-feel" method used by experienced persons. That this method has considerable merit is borne out by manufacturing experience, but it is seriously limited by being entirely dependent upon personal judgment and the fact that no quantitative results are possible. Despite, moreover, the skill of many experienced operators in judging one particular type of body psychological effects and prejudice may be rather important, uncontrollable variables.

(*b*) The Emley plasticimeter[10] has been used for testing clays. This test simulates the action of a jiggering tool in pressing the clay against a plaster mold. It depends on the assumption that the combined properties, water retention and resistance to deformation, are a measure of plasticity.

The plastic clay is placed on a porous plaster of Paris disk of controlled properties which is mounted on a vertical shaft. As the threaded shaft revolves, the clay is elevated with a spiral motion against a conical metal disk. The motion of the metal disk in contact with the clay is resisted by a lever and bar arrangement which tends to restore the disk to its original position. An equilibrium condition is finally reached when the force of the clay against the metal disk is equal to the gravity force of the lever and bar system. The average relative tangential force for the first 5-min. period is used as the index of plasticity. The force obviously increases with the absorption of water from the clay by the plaster base.

(*c*) Mellor[11] describes a ball deformation test which obtains a relation between the amount of deformation and the resistance to deformation. A sphere of clay, 2 cm. in diameter, is placed on a glass plate, and the vertical movement of a piston pressing against the sphere is measured. The load is applied to the piston by means of shot, and deformation continues until the sphere cracks. Although this test is unsatisfactory, it seems to be a forerunner of other more successful methods.

(*d*) A compression method used by the Edward Orton, Jr., Ceramic Foundation is useful for rapid tests. A small plastic clay disk of definite size is placed on the flat surface of a piston which is raised vertically by compressed air in one quick thrust. The clay mass is forced against an upper plate whose movement is resisted by an amount indicated on a calibrated gauge. This test is simple and may be particularly useful for plant control when it is correlated with a more refined compression method such as that of Russell and Hanks.[12]

(*e*) Blair and Coppen[13] used a modified compression apparatus to investigate a wide variety of materials, including two clays. Using constant stress, observations were made on shearing stress as well as other properties such as work-hardening, structural viscosity, and dilatancy. An equation has been worked out which yields impersonal results and which can be adopted to torsion, extension, and compression methods. The judgment of "firmness" by this method has a rather general application. More detailed information is needed, however, before it can be evaluated for the study of clays.

(5) Miscellaneous Evaluations

(*a*) A hydroscopic water-adsorption method used by Keppler[14] indicates plasticity. The amount of water adsorbed by various clays when kept over a 10% hydrochloric acid solution is determined. The more plastic clays generally adsorb the higher amounts of water. This would seem to be a measure of plasticity as related to fineness and colloidality.

(*b*) The malachite green test[15] has often been used to indicate the colloid content of various clays. In this test, a standard malachite green solution is added in controlled amounts to a dilute clay-water suspension of known concentration. After thorough digestion, a sample of supernatant liquid is removed and compared colorimetrically with a malachite green solution of known concentration. The amounts of dye adsorbed by different clays are calculated to give values which are comparable. This test does not actually measure the colloid content, but rather the adsorption power of the colloids present, as variations due to associated salts and the nature of colloidal constituents are undoubtedly effective.

(*c*) The calculation of base-exchange capacities seems to be another useful method of indicating relative plasticity. Clays can generally be rated in their order of plasticity by the quantity of exchangeable bases present.

One simple method which has been used is to digest a weighed amount of clay in $N/10$ hydrochloric acid for 1 hr. After the clay has settled, a sample of supernatant liquid is titrated with standard alkali, and the result is reported as "exchangeable bases in m.e. per 100 gm. of sample." It is usually expedient to calculate all exchangeable bases as Ca, but this is arbitrary. Actual determinations of the amount of each exchangeable base can be made if such information is desired.

Any of the accepted methods of base-exchange determination may be used. The foregoing method is described, however, because of its relative simplicity. Another fairly simple method which may be preferred is digestion with a neutral salt, such as ammonium acetate. After digestion, the decanted liquid is evaporated, and the residue is heated over a hot flame to drive off the combined acetate. The oxides or carbonates remaining are then titrated as previously described.

Such determinations are related to the nature and amount of exchangeable bases and to the colloidal condition of the clay, so that any base-exchange evaluation of plasticity will be largely dependent upon these factors. The suggested methods do not isolate soluble salts from exchangeable bases, so that any refined method should provide for the removal of soluble matter prior to the determination of base-exchange capacity.

(*d*) Inasmuch as particle size is recognized as an important factor in governing plasticity, any of the reliable methods of particle-size determination should be useful. Numerous methods have been proposed and used for these determinations, and those based upon sedimentation according to Stokes' law have been the most popular, e.g., the Andreasen pipette,[16] the Wagner turbidimeter,[17] hydrometer methods,[18] and various elutriation methods. The microscopic method of determining particle sizes and distribution has been used and in some cases is preferred. Centrifugal force for separating particle-size fractions has been used more recently, and the development of supercentrifuges operating at 50,000 r.p.m. or more is increasing the possibilities.

(*e*) Any measure of the water of plasticity of a clay or body is related to plasticity, and it is generally assumed that the water of plasticity is directly proportional to plasticity. Unfortunately, there is considerable personal element involved in most water-of-plasticity determinations. The use of such information to indicate plasticity depends in large part, therefore, on the development of impersonal, duplicable test methods.

The liquid limit test[19] developed to study surface and subsoils should be useful for obtaining a fairly reliable value which may be called water of plasticity. Another method requiring more elaborate equipment is the determination of "moisture equivalent," as suggested by Russell and Hanks.[12]

(*f*) The bonding power of clay is a property closely related to its plasticity. Methods of testing the cohesiveness or stickiness of plastic clay masses have already been described. It appears, however, that dry bonding strength is another means of evaluating certain plastic characteristics, and a transverse strength test on dry, unfired bars should be considered. In making such tests, it is generally desirable to include nonplastics as well as clay in the mixture; a 50 clay–50 flint combination is the usual standard.

(*g*) Another test which might be related to plasticity is the determination of heat-of-wetting values. Such values would undoubtedly be related to base-exchange capacity and particle size. Whether the information would be useful in the evaluation of plasticity is a matter of conjecture.

III. Discussion

Many methods other than those described could undoubtedly be used to obtain the same or comparable information. Any selection of test methods should depend upon the specific application involved.

In the laboratory study of clays and bodies, it would be

desirable in most cases to use tests which indicate one individual characteristic related to the composite property known as plasticity. The results of several different types of tests when considered together may then well evaluate a clay in regard to plasticity. Tests which indicate the combined effect of several factors which control plasticity may also be useful in the analysis. In some cases, simple test methods may be so correlated with the more refined and tedious methods that only the simpler tests need be made. For any plant control usage it will be necessary to adopt simple, rapid methods which do not involve elaborate equipment, and, in this case, correlation to laboratory tests may be extremely useful and time-saving.

The plasticity of ball clays, in regard to both working and bonding characteristics, is one of their outstanding and useful properties, and no selection or evaluation can be completely satisfactory without due consideration for the composite property, plasticity.

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CASTING-RATE TESTS*

By C. M. Lambe

I. Introduction

The casting rate of a clay is determined (1) to substitute one clay for another in a given body, (2) to change the relative proportions of clays, and (3) to be sure that a particular clay is behaving normally.

Nearly all laboratories, when casting a small disk, plate, or cup, consider either the dry or plastic weight as the casting rate. These tests vary widely in size of piece, length of casting time, and in such physical properties of the slip as specific gravity, method of preparation, and degree of deflocculation.

When the casting rate was first considered in this plant, the testing method was thought to be immaterial so long as all data were relative. When later trials on a semiproduction basis proved this assumption to be erroneous, various tests were tried in an effort to secure reliable data.

II. Equipment

The following equipment was used for the tests: (1) a specific-gravity bottle and balances, (2) an open-top, Mariotte-type, brass viscosimeter, (3) $^1/_8$- and $^1/_{30}$-h.p. Lightnin mixers, (4) assorted pans and buckets, (5) molds ranging from tea-cup to bucket size, (6) clays to be tested, (7) a 100-mesh sieve, and (8) timing equipment.

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III. Procedure

The slips for testing were prepared in 10,000 gm.- to 100-lb. batches by blunging raw materials and water with one of the mixers. Sufficient soda ash and sodium silicate were used to obtain deflocculation comparable to plant practice. Barium carbonate was used when necessary. When blunging was completed, the slip was run through a 100-mesh sieve and cast immediately.

The molds used were all made from the same batch of plaster and were cast once daily to keep them in condition.

Test 1: Ball-clay slip was cast for 1 min. at a specific gravity of 1.500 in a mold about tea-cup size. The cast was drained for $1^1/_2$ min., and the casting rate was measured in grams of dry clay cast per min.

Test 2: Ball-clay slip was cast for 30 min. in a mold holding one quart of slip. Drainage lasted $1^1/_2$ min., and the casting rate was considered to be the dry weight of the cup.

Test 3: Fifty per cent of flint was added to the ball clay and the specific gravity raised to 1.815. The slip was cast in the quart-sized mold for 30 min., drained $1^1/_2$ min., and allowed to dry in the mold for 10 min. The plastic weight of the cup was the measure of the casting rate.

Test 4: The clay was incorporated in a reasonable percentage into the production body slip, which was again

cast for 30 min., drained 1½ min., and dried 10 min., and the plastic weight was the measure of the casting rate.

Test 5: The thickness of cast, rather than the wet or dry weight, was made the criterion. Ball clay-flint and body slips were cast in a bucket-sized mold, and plastic and dry thicknesses were obtained at 30-, 60-, and 90-min. intervals by progressive draining.

The value of a test was determined by the fidelity with which it indicated results later obtained on a semiproduction basis.

IV. Analysis of Tests

(1) General Considerations

The success of a casting-rate test greatly depends on the closeness with which production conditions are simulated. The most important determinants in this simulation are (1) size of batch, (2) size of specimen, (3) length of casting time, and (4) slip properties.

One-hundred pounds of dry material are needed in our laboratory to secure a reasonably representative sample of clay, to have enough slip to make a small test after each addition of deflocculant, and at the same time have enough slip to test properly. Although larger batches give better results, this is the biggest batch which can be made conveniently in the laboratory.

Unusually small specimens (smaller than a large iced-tea glass) are disadvantageous because (1) they force the tester to measure casting rate more closely than it can be determined or duplicated, and (2) they are thrown in error by the weight of slip which fails to drain off and which collects at the bottom of a cup to indicate the casting rate in a weight test.

As neither the weight nor the thickness of cast is directly proportionate to casting time, it is important to have a long enough testing time. According to data presented by Norton,[1] casting is brought about partly by the flocculation of clay immediately next to the mold surface. This is seemingly the result of a base-exchange reaction in which the Na^+ ion in the clay is replaced by the Ca^{++} ion from the plaster mold; the $SO_4^=$ ions released at the time also probably have an inhibiting effect. This type of casting occurs most readily with fine-grained clays, giving them a definite initial advantage over coarser clays. In a 1-min. test on a cup-sized specimen, this error shows a 23% increase in dry weight when 7% of Jernigan ball clay is replaced with 7% of Old Mine No. 4 in a particular blend of ball clays.

For an accurate test, the slip should be at the specific gravity and degree of deflocculation ordinarily used in production. The biggest source of error is a false casting rate which is caused by poor drainage of under-deflocculated slip. This problem is accentuated in small batches because doping is more difficult.

(2) Tests of Ball Clay Alone

Tests using ball clay alone, regardless of whether thickness or weight was measured, were unsatisfactory. Such tests are misleading because (1) a clay will frequently behave entirely differently when made up in a body slip and (2) ball-clay slips are susceptible to over-doping. In fact, the biggest problem in the correct preparation of ball-clay slips is that of doping, because a viscosity determination is practically the only means of measurement. As fine-grained clays ordinarily have higher viscosities than coarser clays, it is bad practice to deflocculate all of the clay slips to the same fluidity, and it is also illogical to deflocculate all clays to minimum viscosity, because coarse-grained clays with high natural fluidity frequently do not need lower viscosities.

Further disadvantages of using ball clay alone are (1) the impractically large amounts of deflocculant needed to obtain a specific gravity over 1.500, (2) the slowness with which the clay alone casts, (3) the difficulty with which intact specimens are obtained, and (4) the failure of such a test to indicate drainage and general working properties.

(3) Flint-Ball Clay Mixtures

Better than ball clay alone is the 50-50 mixture with flint. Such a slip more nearly approximates a body condition in specific gravity and doping, casts at an easily measured rate, dries well, and gives some indication of general behavior. It does not, however, show how the clay will act when mixed further with feldspar and china clay. Such a mixture is satisfactory for control tests on a particular clay after the standards on deflocculation are determined.

(4) Finished Body Slip

The best results were obtained in all tests run when the clay to be tested was used in a reasonable percentage to make a body slip. Although such a slip is more trouble to prepare, its superiority justifies the additional work.

(5) Weight vs. Thickness as a Criterion

Regardless of the particular test used, thickness uniformly gave better data than either plastic or dry weight. It was impossible to secure either positive correlation or consistent results when the weight of a specimen was used.

Tests run daily over a 2-yr. period to control deflocculation showed that, even with the same slip, identical specimens cast simultaneously would vary as much as 20% in plastic weight. This variation is particularly pronounced among different slips, for the relation between weight and thickness seems to be different for each body. One slip, therefore, may possess excellent properties at a specific plastic weight, but a slight change in body composition so upsets this relation that it may be (1) thicker or thinner at the same weight, (2) thinner at a greater weight, or (3) thicker at a lower weight.

Because of the very nature of a weight test, the sample must be handled as little as possible before weighing. The ease with which data on drying, drainage, and general feel are obtained is therefore greatly limited.

There is a tendency in work with weight tests to put too much emphasis on insignificant changes because of the accuracy with which a weighing is made. In other words, accuracy of from 5 to 10% on an ordinary balance is so ridiculously easy that it is hard to refrain from considering the weight changes which are not important.

Plastic weight helps to confirm a thickness, if the data are properly interpreted.

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[1] F. H. Norton, 21st Progress Report, Phase c, Project 5g, Massachusetts Institute of Technology, Cambridge, Mass.

A thickness test, which eliminates most of the disadvantages already enumerated, is desirable because of the following features: (1) it is a logical, fairly dependable measure of casting rate; (2) it gives valuable indications of drainage, drying, and working properties; (3) the progress of casting may be determined by intermittent drainage; (4) the casting of a sample may be so large that weighing would be impracticable; (5) thickness tests are not so sensitive to changes in weather and mold condition as weight tests; and (6) such sources of error as poor drainage are minimized.

V. Conclusions

(1) The size of the specimen and the casting time should be commensurate with the ware into which the clay is to be made.

(2) Tests on ball clay alone are neither convenient nor accurate.

(3) Tests using a ball clay-flint mixture are fairly well suited to control work, but are not so desirable for research as finished body slips.

(4) Tests using thickness of cast are superior in every respect to those which use weight.

(5) No test was reliable enough to serve as the whole basis for a major change in a production setup.

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Discussion

J. R. BEAM: When working with the casting rate or rate of deposition of ceramic compositions on plaster molds, you generally adopt a test for some particular operation. If you have 10 minutes to make a test before another electrolyte addition, a 10-minute test is established. If 30 minutes are available, a longer casting test can be established. The rate at which casting time changes is a better criterion than any single test cast; in other words, a comparison of the first derivative of the rate of cast is probably a better way to judge the castability of slips.

In a previous discussion, the use of the electronometer or the glass electrode in making pH measurements was mentioned. It is a good thing to run pH measurements on experimental casting slips because you can find out immediately whether or not you are overdeflocculating. The rate-of-cast tests do not show this up nearly so well as the electronometer.

C. M. LAMBE: The casting rate definitely changes, being much faster at the beginning of casting and proportionately slower with the elapsed time. For this reason, it is poor practice to try to ascertain the casting rate of a slip that is to be cast for 90 minutes by trying to cast in a shorter time in tests.

We have had poor correlation, furthermore, between deflocculation and pH; for our particular body, it is practically useless to determine pH.

L. E. THIESS: Why do you use such a low specific gravity?

C. M. LAMBE: The tests on bodies consisting of 50% ball clay and 50% flint and regular production slip were run at a specific gravity of 1.815. The tests on ball-clay slip alone were run at a specific gravity of 1.420. The reason the ball-clay specific gravity is low is that the ball clay is processed first, other materials are then added, and measurement is made volumetrically in a cylindrical tank. The specific gravity must therefore be varied according to the percentage of ball clay in the body.

L. E. THIESS: If you ever want to get something out of these tests, the best way is to test the body that is actually being used in the plant.

C. M. LAMBE: I agree with you. The closer you make the test slip to the slip actually being used, the better data you will get. Although a clay mixture of 50% flint and 50% ball clay is better than ball-clay slip alone, it is nowhere near a regular body. The closer you get to the body you are using, the better the results, whether weight tests or thickness tests are used.

D. E. POSTLEWAITE: Based largely on data developed by A. O. Knecht, we have found the ratio of sodium carbonate to sodium silicate to be important in the casting-rate problem. Would you suggest the adoption of a constant ratio between these two and should the amount of aging of the slip be considered? These factors seem to have a marked effect on the casting rate.

C. M. LAMBE: In regard to the ratio between sodium silicate and barium carbonate in the type of production in which we are engaged, it is impossible to set this because of the varying amounts of soluble salts in the clays. We have made every effort to trace the effects of changes in barium carbonate and sodium silicate in grade A ware and shop loss, but we have found no apparent relation. The process is to deflocculate the slip as far as necessary by means of the "feel" test and then complete deflocculation by making test casts of pieces of the ware.

Relative to aging, our production is set up in such a way that the slips are aged regularly for three days. That is as far as we can get ahead, and we cannot afford to get any further behind. In production, then, we are aging that definite time and also on test runs. We make test casts as soon as the slip is completely mixed to minimize the time required for correct deflocculation. At one time when we had a strike, the slips were aged for 2 weeks. When operation was resumed, they worked very much better. We cannot age that long, however, as a regular thing.

L. E. THIESS: Do you control the temperature when you make casting tests?

C. M. LAMBE: The temperature of the final slip does not vary a great deal because it is agitated beneath the floor in a pit approximately seven feet deep. In year-round temperature, it does not vary more than 5° running close to 90°F. In the production process between summer and winter the maximum temperature difference is from 102° to 68°F. The final temperature of the casting slip is fairly closely controlled because of the previously mentioned pit and also because it is constantly circulating through the shop.

A. L. JOHNSON: I wondered if you found any difference in your casting tests using new molds and molds that had been in service for a while.

C. M. LAMBE: There is a considerable difference in the casting rates indicated by old and new molds. The average life of these small molds is about a year, after which time the discrepancy between weight and thickness widens. To minimize this difference, each mold is cast every day. In any event, the change is so small over a short period of time that it is not serious.

OXIDATION OF BALL CLAYS*

BY G. A. BOLE

In an endeavor to determine current ball-clay testing practice, letters were sent to the largest ball-clay users in each of the four fields where ball clays are used. These companies all maintain control laboratories. With one exception, they answered that they make no routine tests on ball clays to determine the rate of oxidation. Most of them, however, have given the matter some thought and

* Received April 23, 1942.

have run tests. They think that a simple test would be used if it were suggested.

One of the replies states that a combustion train is used to determine the carbon in a clay when the clay is first used, but no control tests are run and none are needed. Another reply states that when English ball clays are used for electrical porcelain manufacture, the clays are cleaned before they are used, and about 3% of the residue (principally lignite) is recovered. Better firing and cleaner clays have obviated the need for controls.

One correspondent says that ball clays are screened through a 120-mesh sieve and that 2 or 3% of lignite remains on the screen. The clay, as used, is not tested for black coring.

Another correspondent states that cast cubes of a clay in use and a clay under test (both mixed with flint in a 50 to 50 ratio) are run through the commercial kiln side by side. The fired cubes are cut, and the internal structure is observed. Extreme care must be exercised in any oxidation tests. In one test, forty-seven identical cubes of a body composed of 50% ball clay and 50% flint were placed in a row across the commercial car-tunnel kiln with cone checks. The samples came through the kiln with 44 of the 47 samples free of black core; the other 3 samples were badly cored. The correspondent suggests that a standard body should be used instead of the clay-flint mix and that great care should be taken in placing the samples on the car decks.

A correspondent making hotel china substitutes ball clay for both kaolin and ball clay in his mix, thus producing a body which contains 43% of ball clay. The body is prepared, and the regular rolled-edge hotel china plates are jiggered and treated as regular ware for the biscuit fire. This test gives color, vitrification, and a tendency to speck, if any, and, when the plates are broken, any black coloring will show. If the test body does not vitrify, this process is repeated with the dolomite increased so that results are obtained on vitreous ware. It has been shown from this test that if a vitreous body black cores when it contains 43% of ball clay a specked ware may be produced when the ball clay is reduced to 10% of the body content. This test can also be run by making the body of ball clay 50 and feldspar 50%. This mixture generally vitrifies to quite a glassy structure and shows any tendency to black core.

Another correspondent suggests A.S.T.M. Specification C–40–33 (Organic Impurities in Sands for Concrete) for evaluating the organic matter in a ball clay. This method, a colorimetric method, was tried at the Ohio State University Engineering Experiment Station with the necessary modifications for a clay. A standard reference solution is made by dissolving a given weight of tannic acid in a given volume of water. A 10% alcoholic KOH solution is added to develop and stabilize the color. KOH is added to the clay suspension, which develops a characteristic color. After standing for 24 hr., the color of the supernatant liquid is compared with the standard, and the clay is given a tannic acid number. This method would have to be standardized for clay and correlated with the tendency to black core under a given set of standard conditions. The test would mean more if it were carried out on the prepared body mix.

There are, of course, many organic compounds in a ball clay. They are not all extracted to the same degree by the KOH solution.

As another approach for a test method, an oxidizing agent might be added to a cube of the clay body under test. If the commercial body is not used, the cubes might be made of a mixture of clay and flint or of an idealized body. A relatively insoluble oxidizing agent must be used to avert its migration to the surface of the test piece. The samples might have to be made up by a plastic press method which would use little water. Different amounts of the oxidizing agent could be added to a series of samples. The firing could be carried out at a low temperature (600° to 2000°F.), and an oxidation number could be arrived at which would compare the speed of oxidation of the clays or bodies.

There is a great deal more in the literature about the oxidation of heavy clay products than about the elimination of black core in whiteware bodies. Orton and his co-workers, the U. S. Bureau of Mines,[1] and the sewer-pipe manufacturers[2] have treated the subject exhaustively. Morgan,[3] at the University of Illinois, studied the oxidation of clays in the combustion train and obtained the most rapid oxidation between 800° and 900°F. As a result of this work, the industry has been "well sold" on the general idea of low-temperature oxidation. Nearly all of the plants which fire whiteware have selected their clays to suit the body mix and their firing conditions so that there is little need for a control test. There is some indication that a purchase specification test would be acceptable. If and when sufficient evidence is offered that a clay can be evaluated in terms of service, some of the more progressive manufacturers will doubtless adopt such a specification.

Engineering Experiment Station
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[1] R. T. Stull, *et al.*, "The Burning Problems of Industrial Kilns." An investigation by the U. S. Bureau of Mines and the four heavy clay products associations, 1924.

[2] (*a*) R. E. Arnold, E. A. Hertzel, C. E. Parmelee, and R. L. Blessing, "The Kiln Investigation." The clay products associations' Industrial Fellowships, Mellon Institute, Rept. No. 86, September, 1928.

(*b*) R. E. Arnold and G. H. Duncombe, Jr., "Clay Sewerpipe Manufacture: VI, Heat-Balance Determinations," *Jour. Amer. Ceram. Soc.*, **12** [6] 410–22 (1929); "VII, Low-Temperature Oxidation," *ibid.*, pp. 423–28; C. E. Parmelee, "VIII, Measurement of Draft Distribution," *ibid.*, pp. 429–33; E. A. Hertzell, "IX, A Method of Checking Flue-Gas Analyses and Its Application to Ceramic Kilns," *ibid.*, **13** [8] 566–70 (1930); R. L. Blessing, "X, Measurement of Moisture Loss in Kilns," *ibid.*, pp. 571–79; R. E. Arnold, "XI, A Simple and Inexpensive Cold-Junction Compensator for Outdoor Pyrometer Installations," *ibid.*, pp. 580–86.

[3] W. R. Morgan, "Relation Between Uncombined Quartz and Thermal Expansion of Ceramic Bodies," *ibid.*, **17** [5] 117–21 (1934).

Discussion

Chairman Russell: Dr. Bole has given us something to consider in the development of oxidation tests. He has made the worth-while suggestion that some ceramic department or research organization take up this study and prove the merits or demerits of the various methods.

I. A. Balinkin: Dr. Bole, what did you use as an oxidizing agent?

G. A. Bole: We used potassium perchlorate.

FIRED COLOR OF BALL CLAYS*

By Isay A. Balinkin

Abstract

Spectrophotometric curves were made of 19 samples of fired ball clays, and the I.C.I. color specifications were computed for illuminant C. These samples indicated a small range in dominant wave lengths extending from 573 to 579 mμ. The apparent luminous reflectance varied from 42.2% for the darkest sample to 86.0% for the lightest sample. The range of purities gave 8.4% for the lowest saturation and 19.1% for the highest saturation. It is pointed out that the spectrophotometric investigation of the reflectances of ball clays should give the answer to various "mysterious" effects in the firing of clay products.

I. Introduction

The fired color of ball clays depends on a complex of physicochemical processes, the exact nature of which is still a debatable subject. The color of alumina and silica is white, and any departure from white must be produced by some additional ingredients in the clay. All investigators agree that in this regard the presence of iron in its various forms is of paramount importance in determining the color of fired clay. The variation in the percentage of iron, usually determined as Fe_2O_3 equivalent, can give the fired ware a color ranging from a white to a dark purple-red. Other constituents usually present in the clay may also either enhance or lessen the color effect of iron compounds. In some instances, a relatively large percentage of iron (as much as $2^1/_2\%$, as found in some Chinese porcelains) can give only a slightly bluish cast to whiteware, whereas in other instances 0.1% of iron produces an objectionable yellowish tint. Titanium oxide, especially when present in the amounts of 1 or 2%, causes a grayish yellow coloration, which is particularly pronounced in the presence of iron.

The bleaching effect of lime is probably the most important agent in mitigating the coloration due to iron. Alumina and magnesia also belong to this class of decolorants.

A graphical representation of the dependence of the color of fired ball clays upon the colorants and bleaching agents present in the clays is shown in Fig. 1. Along the abscissa, the percentage of various coloring ingredients is given as a summation of Fe_2O_3, TiO, MnO, etc. The coefficients k, l, etc., represent the coloring strength of each one. These coefficients are not necessarily constants, but may be functions of the other compounds present. Along the ordinate, the percentage of various bleaching compounds is also given as a summation of CaO, MgO, etc. The coefficients a, etc., represent the bleaching strength of these ingredients. In the coordinate space of these two variables, the hue range of fired ball clays from white to ivory, yellow, orange, and red can now be designated. The buff colors will be located on the borderline between orange and red.

The direction of increasing percentages of colorants corresponds to decreasing lightnesses and increasing saturations. The direction of increasing percentages of decolorants corresponds to increasing lightnesses and decreasing saturations. The exact evaluations of the numerical specifications of such a graphical representation must be left to the future. The purpose of Fig. 1 is to give a simple graphical picture of the dependence of color on the chemical composition of the ball clays.

The subject of establishing a definite relationship between all of the factors affecting the color of fired ball clays is beyond the scope of this paper. Searle and Wilson[1] discuss extensively the effects of different iron compounds, their particle size, distribution and mineralogical state, temperature and rate of firing, presence of various bleaching oxides, and the atmospheric conditions in the kiln.

Clays can be divided into two large color groups, viz., (1) the white- and yellow-firing clays and (2) the yellow-to-red-firing clays used in firebrick. Only the first group of clays will be considered in this paper.

II. Color Specification

The general subject of color specification was adequately discussed at the recent Symposium on Color Standards and Measurements.[2] If we do not know today more about the exact nature of different factors which affect the color of fired clays, it is because, as stated by Searle,[3] "the measurement of the color of clays and other rocks and the products made from them has not reached a stage where it can be done accurately." This statement was true ten years ago; today the science of colorimetry offers an exact numerical method of color specification. More than that, the availability of instruments which graph a spectrophotometric curve gives the information which reveals even more than just the color of a fired ceramic material.

Some of the available methods of specifying the color of fired ball clays are listed as follows:

(1) Color Names

A simple and usually vague method of color specification is to give a color some name. Because the human eye can see several million different colors, it is immediately apparent that for an exact specification such procedure is hopeless. This is probably the reason why one color name has to cover a multitude of sins. Unfortunately, color names are used exclusively at present in specifying the color of fired ball clays. A cursory examination of the literature, both periodical and producers', reveals an array of color

* Received August 10, 1942.

[1] (*a*) A. B. Searle, Chemistry and Physics of Clays, 2d ed., pp. 113–43. Ernest Benn, Ltd., London, 1933, 738 pp.; *Ceram. Abs.*, **13** [2] 50 (1934).
(*b*) Hewitt Wilson, Ceramics—Clay Technology, pp. 158–71. McGraw-Hill Book Co., Inc., New York, 1927, 296 pp.; *Ceram. Abs.*, **6** [11] 547 (1927).

[2] "Symposium on Color Standards and Measurements, I–V," *Bull. Amer. Ceram. Soc.*, **20** [11] 375–402 (1941).

[3] A. B. Searle, *loc. cit.*, p. 143.

names such as perfectly white, white, whitish, pale cream, very light cream, cream, deep cream, slightly yellowish, ivory, rich ivory, cream-white, gray-white, grayish white, and others. It is anybody's word that a given sample of fired clay answers any or some of these color specifications.

(2) Material Color Standards

A much better method of specifying a color is to refer that color to a visually equivalent material color standard. Such material color standards are usually organized into color systems with appropriate color notations, such as the Munsell, Ostwald, and Maerz and Paul systems. It would be a step in the right direction if clay producers would give color specifications in one of these three systems. Munsell notations have been used extensively in many branches of industry, and Munsell standards have been placed on the imperishable basis of exact numerical specifications.

A recent publication[4] gives color names and standards in the form of 56 colored chips for colors of soils. Color notations have been worked out by the Inter-Society Color Council and the National Bureau of Standards. A similar color dictionary might be prepared for the color nomenclature of fired ball clays.

(3) Trichromatic Colorimetry

A less direct method of color specification is based on the possibility of matching any color by a proper selection of various amounts of three colored lights. This also means that the amount of light reflected by a sample in the three chosen spectral ranges can be considered to be a unique color specification. In a Hunter multipurpose reflectometer,[5] three filters and two photoelectric cells are used to determine the color equivalence of a given sample. This instrument is finding an ever-widening field of usefulness in ceramic color technology, and its use for color specifications of fired ball clays should be considered.

(4) Spectrophotometry

The most accurate and revealing method of color specification is based on the measured amount of light reflected by the sample throughout the visible spectrum. The success of the Hardy recording photoelectric spectrophotometer in drawing a rapid and reproducible spectral reflectance curve has made possible the application of modern colorimetry in determining exact numerical color specifications. The structure of this method rests on the foundation created by a set of resolutions adopted by the International Commission on Illumination (I.C.I.) in 1931, which provide three primary light sources, the luminosity curve for a normal observer, specifications for three illuminants, and a method of color representation in a standard coordinate system. In fact, the numerical definition of color may be considered to be the end result of a set of operations based on the I.C.I. method of computations. These are some of the reasons for presenting the color of fired ball clays in the I.C.I. system.

III. Samples of Fired Ball Clays

To place the color of various ball clays on the same comparative basis, samples should be prepared and fired under identical physical and chemical conditions. Unfortunately, lack of time did not permit such a procedure. Instead, letters were sent to several clay-producing companies requesting a set of representative fired ball-clay samples. Of the samples received, nineteen were used for spectrophotometry. One sample showed such an appreciable color variation from one side to another that two areas 1 in. in diameter were spectrophotometered. The surfaces of all samples were ground off to eliminate the skin, which in some instances is of an appreciably different color than the body of the samples.

The samples were designated as follows: a, b, c, d, e, A B, C, D, E, and F (same sample), G, x, 6, 11, 12, 13, 14, 15, and 16. The most recent chemical analysis of the ball clays from which the samples were prepared is given in Table I. The samples designated by numbers were available at the Cambridge Tile Manufacturing Company plant; samples 6, 13, and 14 were made of the same clay as samples A, C, and B, which were supplied by the producer. It was interesting to find out the extent of color variation between each pair of these three samples.

[4] T. D. Rice, Dorothy Nickerson, A. M. O'Neal, and James Thorp, "Soil Color Name Chart," *U. S. Dept. Agr. Miscellaneous Pub.*, No. 425 (1941).

[5] R. S. Hunter, "A Multipurpose Photoelectric Reflectometer," *Jour. Research Nat. Bur. Standards*, **25** [5] 581–618 (1940); R.P. 1345; *Ceram. Abs.*, **20** [7] 175 (1941).

TABLE I

CHEMICAL COMPOSITION OF BALL CLAYS

Name of clay	Notation	SiO_2	Al_2O_3	CaO	MgO	TiO_2	Fe_2O_3	Na_2O	K_2O	SO_3	Ignition loss
Hanover	E, F	59.0	27.1	0.30	0.50	1.00	1.50	0.90	0.70		09.1
Royal	B, 14	49.0	29.1	0.11	None	1.70	0.74	0.51	1.69	0.14	17.0
Rex	C, 13	53.7	30.0	Trace	None	1.78	0.88	0.44	1.74	0.10	17.4
Victoria	A, 6	53.7	28.2	0.27	0.07	1.56	0.82	0.43	0.54		14.4
Bedminster	G	52.8	31.8	0.26	0.46	1.43	0.71	1.18	2.35		09.5
Churchill	D	46.1	36.5	0.72	0.33	0.60	1.13	0.58	1.80		12.2
Tenn. No. 1 SGP	a	47.3	34.9	Trace	None	2.82	0.60	0.04	1.06		13.1
Tenn. No. 5	b	54.8	29.5	0.17	0.07	1.23	0.85	0.41	1.76		11.1
K. T. Ivory	c	57.9	26.4	0.19	0.40	2.37	0.69	0.37	0.08		11.5
Martin No. 5	d	60.7	25.5	0.08	Trace	1.39	0.74	0.40	1.72		09.4
Old Mine No. 4	e	51.6	31.2	0.20	0.50	1.72	1.17	0.58	0.36		12.1
Dresden	x	54.0	30.6	0.44	0.51	1.07	1.62	0.31			11.5
Gray	11	56.2	30.0	0.26	0.24	1.81	1.05	0.79			09.9
Dark	12	53.0	30.4	0.35	0.36	1.40	0.91	1.01			12.6
Challenger (?)	15	49.5	31.2	0.08	0.08		0.11	0.73			18.2
Champion (?)	16	46.2	33.8	0.10	0.05		0.13	0.65			19.0

IV. Spectrophotometric Curves

The spectrophotometric curves in Fig. 2 were made on a Hardy recording spectrophotometer at the Electrical Testing Laboratories, Incorporated, New York, N. Y. Each sample shows a minimum reflectance at the violet end and a maximum reflectance at the extreme red end of the spectrum. The variation in the reflectance from one to the other end of the spectrum exhibits a certain amount of individuality for some of the samples.

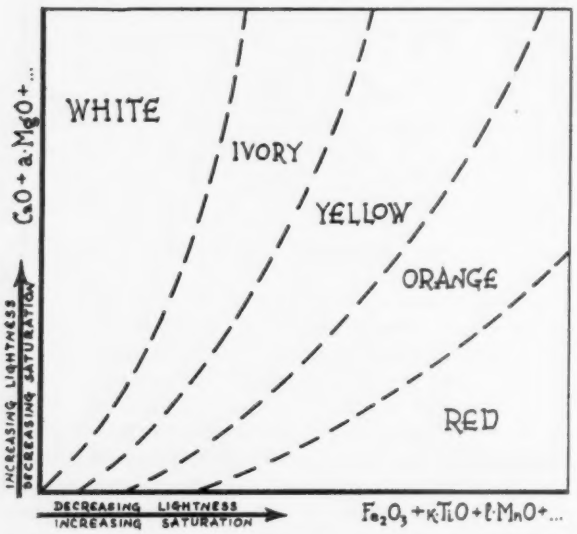


FIG. 1.—Schematic representation of fired ball clay colors which depend upon the colorant and bleaching constituents in the clay.

The rate of increase in reflectance with increasing wave length is at a maximum at 400 mμ, and the rate gradually decreases to a minimum of 700 mμ for all samples. The range between 430 and 570 mμ for sample G is substantially a straight line, i.e., the reflectance is directly proportional to the wave length. Samples E, F, and x show a pronounced absorption band between 450 and 530 mμ. A

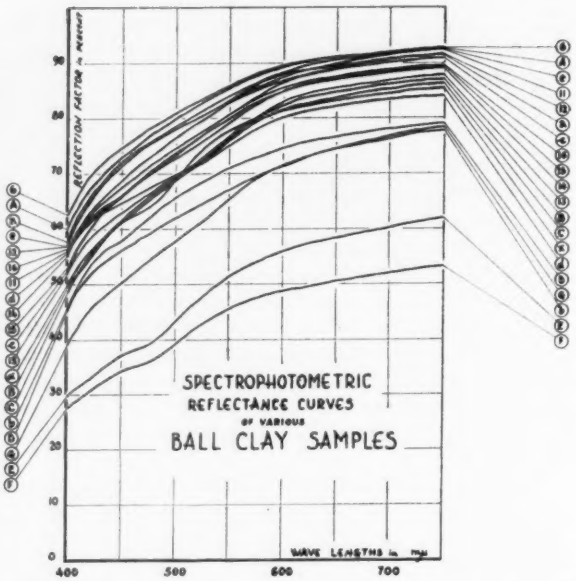


FIG. 2.—Spectral reflectance curves of various fired ball clay samples.

careful study of such spectrophotometric curves may lead to a specific knowledge in regard to some ingredients in the clay or some chemical reactions which take place during firing.

An examination of curves E and F obtained on the same sample indicates that the large color variation was produced by differences in the oxidizing conditions during firing.

The spectrophotometric curves in Fig. 3 are taken from Fig. 2 to bring out the relationships for samples 6 and a, 14 and B, and 13 and C, which were made of the same clay, but were made and fired to the same temperature at two different laboratories. They emphasize the essentia need for identical methods of preparation and firing, if comparable color results are to be expected.

TABLE II

TRICHROMATIC COEFFICIENTS AND I.C.I. COLOR SPECIFICATIONS OF VARIOUS BALL CLAYS FOR ILLUMINANT C

Reflectance rank order	Notation	Ball clays	x	y	z	λ	ρ	P
1	6	Victoria	0.3252	0.3325	0.3422	576.8	86.05	8.4
2	A	"	0.3271	0.3348	0.3381	576.3	85.52	9.6
3	12	Dark	0.3279	0.3356	0.3365	576.8	84.14	10.0
4	e	Old Mine No. 4	0.3274	0.3341	0.3385	577.2	83.60	9.5
5	11	Gray	0.3312	0.3375	0.3312	577.6	83.38	11.3
6	a	Tenn. No. 1 SGP	0.3257	0.3321	0.3422	577.5	83.15	8.4
7	16	Champion	0.3304	0.3364	0.3331	577.9	81.12	10.9
8	c	K. T. Ivory	0.3331	0.3387	0.3281	578.0	80.96	12.1
9	15	Challenger	0.3271	0.3401	0.3327	573.0	80.44	11.0
10	14	Royal	0.3312	0.3362	0.3327	578.2	79.69	11.0
11	x	Dresden	0.3347	0.3430	0.3224	576.4	77.16	13.8
12	13	Rex	0.3341	0.3377	0.3282	579.1	77.07	12.1
13	B	Royal	0.3350	0.3402	0.3248	578.1	76.96	13.1
14	C	Rex	0.3346	0.3402	0.3252	578.0	76.24	13.0
15	d	Martin No. 5	0.3286	0.3330	0.3383	579.0	75.56	9.5
16	D	Churchill	0.3310	0.3390	0.3299	576.4	71.04	11.8
17	b	Tenn. No. 5	0.3310	0.3361	0.3329	578.3	67.41	10.9
18	G	Bedminster	0.3407	0.3450	0.3143	578.5	65.83	15.9
19	E	Hanover	0.3462	0.3514	0.3024	578.1	51.14	19.1
20	F	"	0.3405	0.3477	0.3118	577.2	45.24	16.6

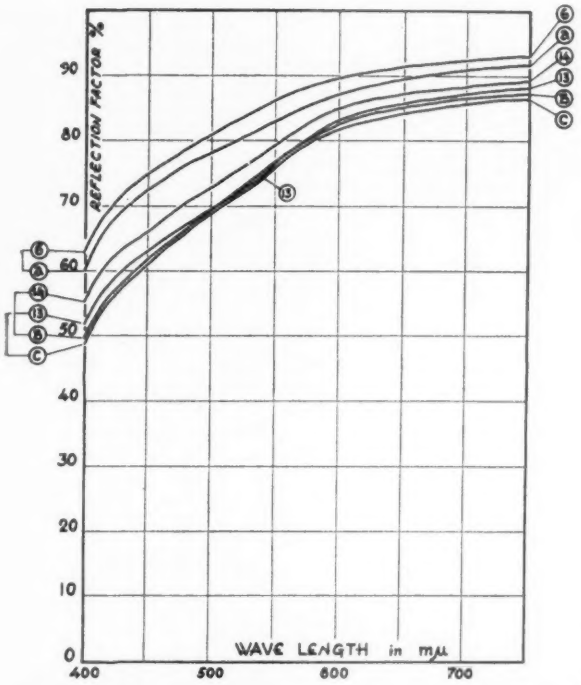


FIG. 3.—Spectral reflectance curves of three pairs of samples. Each pair is of the same clay but made and fired in different laboratories.

V. I.C.I. Color Specification

Following a standard procedure, the curves shown in Fig. 2 were used to evaluate at 10-mμ intervals the I.C.I. color specifications for illuminant C. The final results are presented in Table II giving the trichromatic coefficients, x, y, z, and the psychophysical color specifications in terms of dominant wave length, λ (hue), apparent luminous reflectance, ρ (lightness), and purity, P (saturation).

A narrow spectral range of only 6 mμ is recorded between 573 and 579 mμ where all the samples fall in regard to their hue. This region practically coincides with what all observers would call yellow.

The apparent luminous reflectance covers a range from about 45% for the darkest sample to 86% for the lightest sample.

The range of saturation extends from 8.4 to 19.1%. There is a general tendency to show a higher saturation for samples of lower lightness.

To judge the *whiteness* of fired clays, all the three color attributes, viz., hue, lightness, and saturation, must be taken into account. Because of the small variation in hue, only lightness and saturation may have to be considered. If the increase in lightness were always accompanied by lower saturation, a single attribute of lightness would be sufficient to evaluate the whiteness of fired ball clays. Such, however, is not always the case.

Acknowledgment

The author wishes to express his appreciation to Girard W. Phelps of the United Clay Mines Corporation, R. C. Meeker of the Kentucky-Tennessee Clay Company, and to Richard Bell of the Bell Clay Company for submitting samples and specifications of various ball clays. Thanks are due to Allan E. Parker of the Electrical Testing Laboratories for taking the spectrophotometric curves and to Charles Hayes of the Cambridge Tile Manufacturing Company for making the trichromatic computations. The author is particularly grateful to Charles H. Burchenal, president of the Cambridge Tile Manufacturing Company, and to R. C. Gowdy, Dean of the Engineering College of the University of Cincinnati, for their material and moral support in carrying out the project here reported.

DEPARTMENT OF PHYSICS
UNIVERSITY OF CINCINNATI
AND
THE CAMBRIDGE TILE MANUFACTURING COMPANY
CINCINNATI, OHIO

Discussion

CHAIRMAN RUSSELL: The problem of fired color is important to some of you. The methods suggested by Dr. Balinkin will be valuable to us in the selection of ball clays for application where fired color is important.

L. E. THIESS: I do not know whether I mentioned in my paper that it is necessary in the ball clays to remove the outer skin in order to get what you actually want to test. After grinding one side you can see the difference in color between the outer surface and the inside of the clay body.

I. A. BALINKIN: I agree that this is an important point. Inasmuch as the specimens that were submitted were ground until the place was reached in which no further change of color occurred, that was taken care of.

CHAIRMAN RUSSELL: We shall now discuss some general considerations more or less related to this ball-clay problem.

CLAYS AND TEST BODIES*

BY R. M. CAMPBELL

This subject suggests four considerations which come under the following headings: (1) standard methods of preparing ball clays for testing; (2) standard mixtures and bodies for test purposes; (3) standard methods of mixing the test bodies; and (4) standard methods of preparing the test specimen.

In any particular plant, a ball clay should be substituted in the normal body for the direct interpretation of results. If the ball clay is the only variable from the standard procedure, the influence of a clay under test can be noted readily.

* Received June 12, 1942.

It is generally agreed that tests made on specimens of 100% ball clay are not reliable. It is extremely difficult to make bars free of air bubbles and laminations, and such bars are difficult to oxidize.

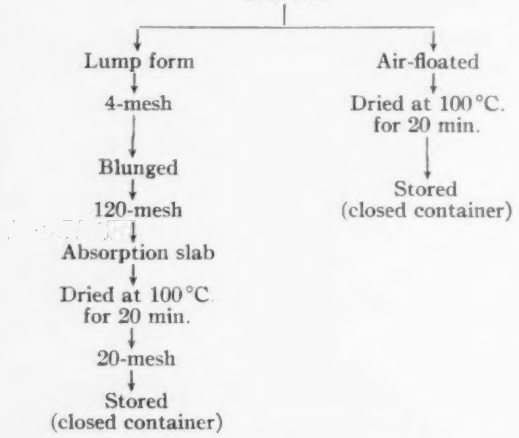
A combination of clay and coarse standard-mesh (20 to 30) sand produces specimens more free of air bubbles and laminations and an open structure more conducive to oxidation. Mechanically, however, these bars are weak. Erratic results are achieved, therefore, in strength tests.

The combination of ball clay and potter's flint gives more satisfactory results than either clay alone or the mixture

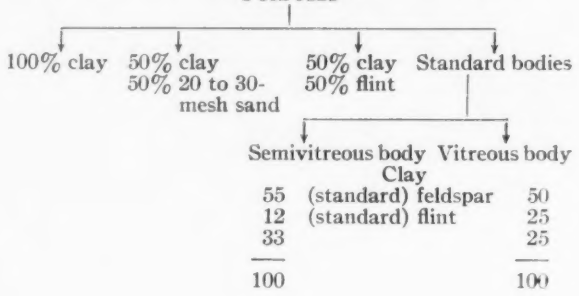
of clay and coarse sand. The amount of flint that should be used is the only question.

Ball clay incorporated into a standard body appears to be the ideal set-up for testing these clays. A combination of feldspar and flint provides the inert material which amounts to and produces the same effect physically as the flint alone. In the fired tests, the results parallel the behavior of a fired body and thus aid in a more direct interpretation of the results. Two standard bodies should be agreed on, one semivitreous and the other vitreous. Proposed bodies are given in the following outline.

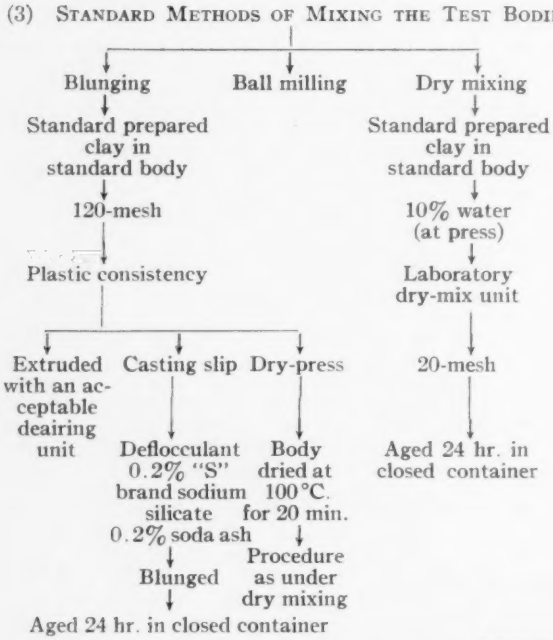
(1) STANDARD METHODS OF PREPARING BALL CLAYS FOR TESTING



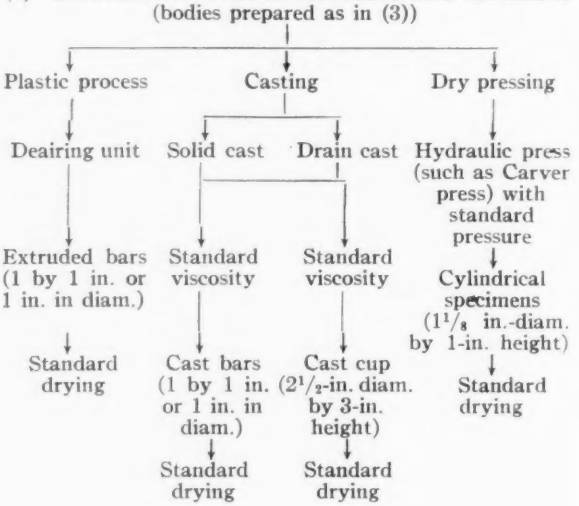
(2) STANDARD MIXTURES AND BODIES FOR TEST PURPOSES



(3) STANDARD METHODS OF MIXING THE TEST BODIES



(4) STANDARD METHODS OF PREPARING TEST SPECIMENS (bodies prepared as in (3))


Plastic process
Casting
Dry pressing
Deairing unit
Solid cast
Drain cast
Hydraulic press (such as Carver press) with standard pressure
Extruded bars (1 by 1 in. or 1 in. in diam.)
Standard viscosity
Standard viscosity
Cylindrical specimens (1 1/8 in.-diam. by 1-in. height)
Standard drying
Cast bars (1 by 1 in. or 1 in. in diam.)
Cast cup (2 1/2-in. diam. by 3-in. height)
Standard drying
Standard drying
Standard drying

NEW YORK STATE COLLEGE OF CERAMICS
ALFRED, NEW YORK

SAMPLE SELECTION AND AGING*

BY C. M. FRANZHEIM

The aging of ball or china clays in the weather or of dampened clay bodies in cellars has a tremendous effect on the value of these materials.

After one year of weathering, ball clays are superior to ball clays used fresh as shipped, owing to the breakdown of the structure by freezing and water washing. Soluble sulfate salts and other salts are washed from the clay and the colloidal nature of the clay is vastly improved because of the "gel."

*Received June 12, 1942.

Weather aging improves ball clay more than any other ceramic material, probably because of the effect of the vegetable matter which it may contain. (This same action occurs in china clays, but to a lesser degree.)

The aging of clay bodies in damp cellars improves a body materially. Cellar aging for one year, for example, can increase the tensile strength of a clay body almost 100%.

Unfortunately, considerable capital is needed to age clays. This is probably the main reason why aging is not used more regularly. Much space is also needed for aging,

and many ceramic plants do not have the required space.

It is difficult to secure average samples from lump ball clays. All samples of ball clay, therefore, should be taken in the shredded form.

Practically all domestic ball-clay producers, as well as some of the importers, shred ball clays. A sample taken anywhere from a bin of shredded ball clay should represent the average, for the process of shredding at the ball-clay mine is so arranged that by the time the material is loaded into the car it has been thoroughly mixed and remixed several times. When it is unloaded into the customer's bin, it is remixed again two or three times.

Users who spend money for shredding do not want to put the shredded clay outdoors to weather. If they did this and had the capital and the space, they would be well repaid by superior bodies with less loss.

C. M. Franzheim Company
Wheeling, West Virginia

TESTING AND CLASSIFICATION OF BALL CLAYS: THERMAL HISTORY*

By C. G. Harman and C. W. Parmelee

All ball clays pass through the same stages and undergo the same types of changes when heated from room temperature to their fusion points. The changes should be considered in two separate groups, viz., (1) those which occur below 1000°C. and (2) those which take place at temperatures above 1000°C. The significant point about group (1) is that corresponding changes occur at approximately the same temperatures in any ball clay. In group (2), the different ball clays pass through their corresponding phases at different temperatures.

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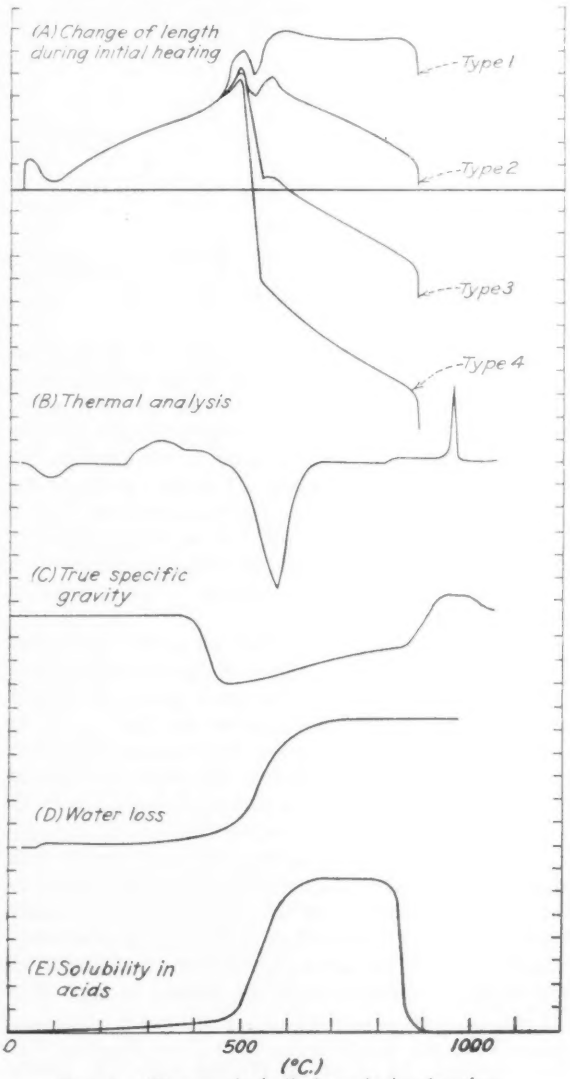

Fig. 1.—Changes in ball clays during heating.

Below 1000°C., the reactions of various ball clays to heat-treatment differ chiefly in the magnitudes of the corresponding physical and chemical changes. Typical variations in several of the properties of ball clays are shown in Fig. 1. A good example of how the magnitudes of corresponding changes may differ among ball clays is illustrated by Fig. 1 (*A*). These curves describe the changes in length of typical clays during their initial heating (in this case, up to 890°C.). The curves for the four radically different types of ball clays all have breaks occurring at the same temperatures, and the clays display their individuality by the magnitudes of the changes between these breaks.

Changes in many physical and chemical properties of ball clays due to heat take place nearly simultaneously. A few such changes are shown in Fig. 1 (*A*), (*B*), (*C*), and (*D*). The shape of each of these curves is fixed by one or more of its fundamental variables, viz., its mineralogical, chemical, and physical composition. The porosity-temperature relationships of different ball clays are similar because they are all composed predominately of kaolinite. The differences between ball clays are due to the nature and extent of dilution of the kaolinite with other minerals and to differences in degree of dispersion.

It is beyond the scope of this paper to go into detail regarding what is known concerning all of these variables and their relation to thermal history. It is more practicable to consider the properties in which we are directly interested. Interest in data concerning ball clays is stimulated by a desire to know how they will behave in actual practice. From this standpoint, one might be justified in saying that the only useful data would be the result of an actual plant trial. In the final analysis, the selection of a ball clay must depend upon its peculiar merits, as demonstrated by such testing, but not before preliminary laboratory tests have shown its possible value. Any other procedure would be too expensive to permit the examination of more than a few samples.

The determination of the fundamental variables of each clay, i.e., chemical composition, mineralogical composition, and the particle sizes of each mineral, would be even more expensive than the plant trials and less informative. Even if these fundamental properties were known, there would still be doubt as to how the material would behave in the shop. Apparently the best to be hoped for at the

present time are methods of testing and classification that can be relied upon to give as much information as possible with a reasonable expenditure of effort. The objective then is a usable classification based on tests by means of which the application of any clay may be readily determined.

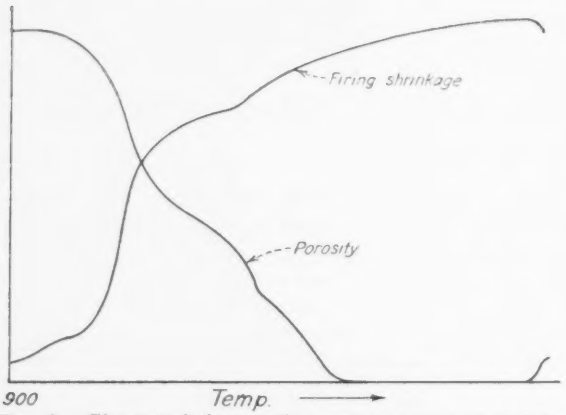

FIG. 2.—Characteristic porosity-temperature and shrinkage-temperature curves of ball clays.

The knowledge of the behavior of the ball clays when heated to temperatures below 1000°C. is useful chiefly in their classification. The magnitudes of the changes in length and the thermal effects are too small to be of much consequence in commercial operation. They do, however, bring out some important distinctions which will be discussed in more detail later.

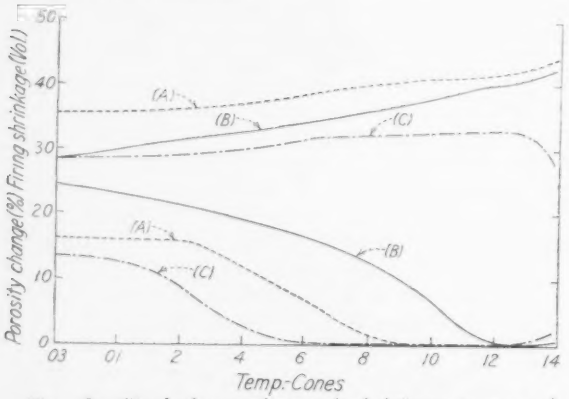

FIG. 3.—Typical porosity and shrinkage curves of ball clays; *curves:* (*A*) dark Paragon; (*B*) Ky. No. 4; and (*C*) brown Paragon (data from C. W. Parmelee and T. N. McVay, "Investigation of Some Ball and China Clays," *Jour. Amer. Ceram. Soc.*, **10** [8] 598–628 (1927)).

The effect of temperatures above 1000°C. on ball clays is of direct commercial importance because it is in this range that rapid shrinkage and vitrification occur and fluxing oxides become active. The shrinkage-temperature and porosity-temperature curves of all ball clays are typified in Fig. 2. Although the magnitudes of the maximum porosities and shrinkages of ball clays vary considerably, the shape of the curve is characteristic of the class, and the corresponding temperatures are characteristic of the individual, although they are subject to some variation owing to fabrication and firing technique.

Shrinkage-temperature curves of ball clays (Fig. 3) are not the inverse of the porosity-temperature curves. The shrinkage and porosity curves are influenced appreciably by the true specific gravity of the fired clay. Changes of true specific gravity of clays during heating (Fig. 4) result directly from changes in the mineral phases present. Only minor changes in true specific gravity take place up to the temperature at which the kaolin molecule begins to dehydrate. At this point, the specific gravity begins to drop suddenly, as would be expected from the theory that dehydrated kaolin is a mixture of amorphous alumina and silica. The specific gravity of the dehydrated mixture slowly increases as it is heated to higher temperatures. This apparently indicates that small amounts of the amorphous oxides are recombining to form a compound. This increase in specific gravity is suddenly increased at about 900°C., which corresponds to the sudden shrinkage shown on the "change in length" curves in Figs. 1 (*A*), 7, 8, and 9. At about 975°C., a sudden evolution of heat is shown on the thermal analysis curves in Figs. 1 (*B*), 10, and 11. This corresponds to the detectable mullite formation as shown by Insley and Ewell[1] and others.

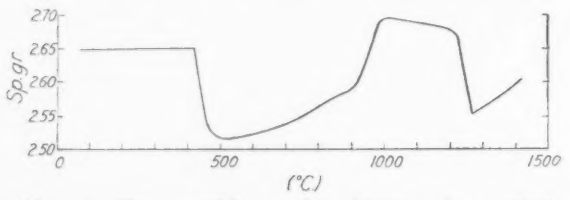

FIG. 4.—True specific gravity changes of a typical ball clay after heating to temperatures up to 1400°C. (data from Parmelee and McVay, see Fig. 3).

Beyond this temperature, the shape of the specific gravity-temperature curve is similar for all ball clays, but the temperatures at which the breaks in the curve occur vary with different ball clays. The drop in specific gravity above 1000°C. is due, in part at least, to the formation of cristobalite and siliceous glass. It seems reasonable to assume that the rapid drop in specific gravity (represented in Fig. 4 as beginning at 1200°C.) is due to the inversion of free quartz to cristobalite and that the following increase in specific gravity reflects the solution of this cristobalite into the glassy phase.

Such specific gravity data, although useful, are expensive and tedious to obtain. Much of the same information can be obtained from other data which are not so difficult to get. The cristobalite development and the free quartz content can be estimated better from thermal expansion data. Generalizations regarding the effect of thermal history on the thermal expansion of ball clays cannot be found in the literature. No cristobalite formation is expected to be present until after the mullite has been formed, or near 1000°C. Cristobalite should then appear and persist until it is dissolved by the fluxing oxides. In early vitrifying clays, this should be over only a very short temperature range, and perhaps in some extreme cases none at all will appear if sufficient fluxes are present to form glass

[1] Herbert Insley and Raymond H. Ewell, "Thermal Behavior of the Kaolin Minerals," *Jour. Research Nat. Bur. Standards*, **14** [5] 615–27 (1935); R.P. 792; *Ceram. Abs.*, **14** [8] 201 (1935).

near 1000°C. In clays with higher vitrification temperatures, cristobalite will form from the free quartz and from the dissociation of the $Al_2O_3 \cdot 2SiO_2$ and persist until a high enough temperature has been reached to cause the cristobalite to go into solution.

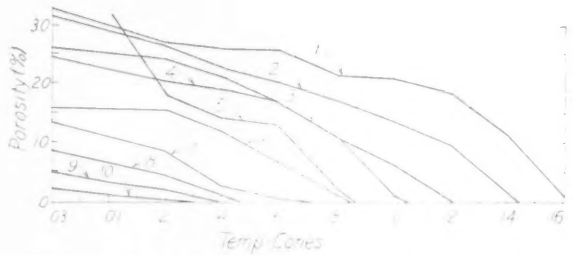

FIG. 5.—Porosity-temperature curves of ball clays showing wide variety of maturing temperatures (data from Parmelee and McVay, see Fig. 3).

Vitrification temperatures vary greatly among the individual ball clays. The examples plotted in Fig. 5 are representative of the range. The vitrification behavior of the ball clay itself might be assumed to have an important bearing on the vitrification behavior of the body of which it is a part. No information can be found to indicate the extent to which this is true. Another factor which has received little attention is the influence of ball clays on pore structure or permeability. Porosity data are useful, but information relating these data with pore structure or permeability could prove most valuable. Such data could possibly lead to a satisfactory correlation

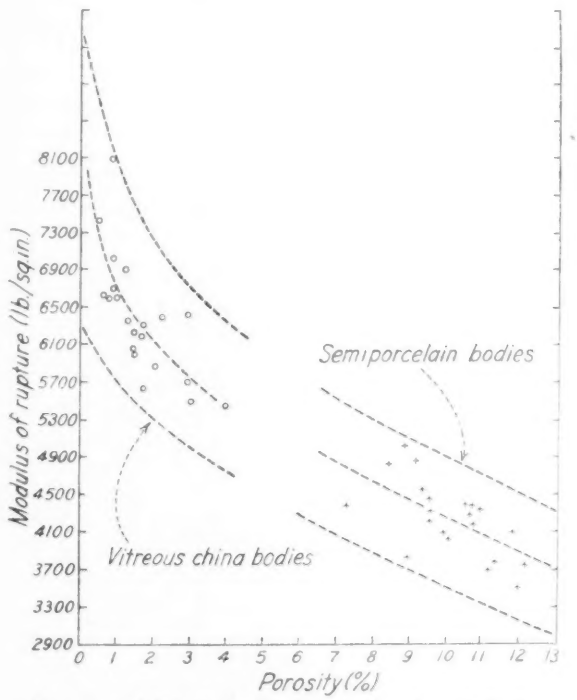

FIG. 6.—Difference in the effect of various ball clays on porosity and strength of bodies (data from H. H. Sortwell, see footnote 2, p. 286).

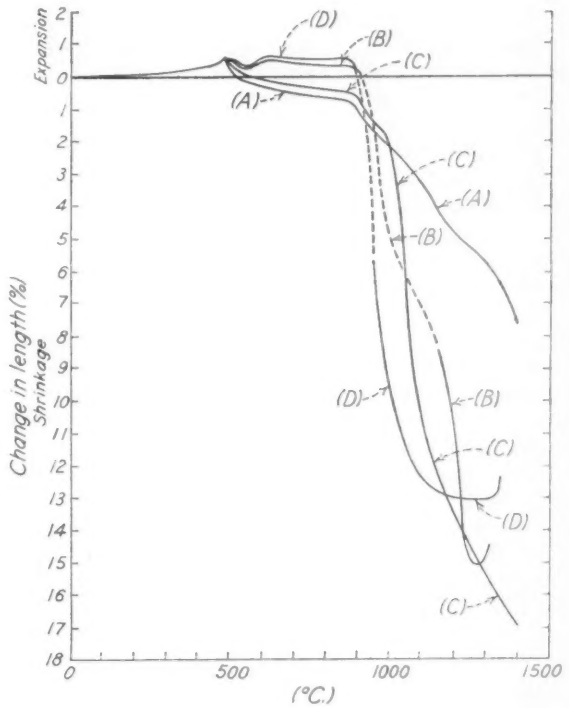

FIG. 7.—Changes in length of ball clays during firing; *curves:* (*A*) S.G.P.; (*B*) Jernigan; (*C*) Ky. No. 4; and (*D*) Dorset English.

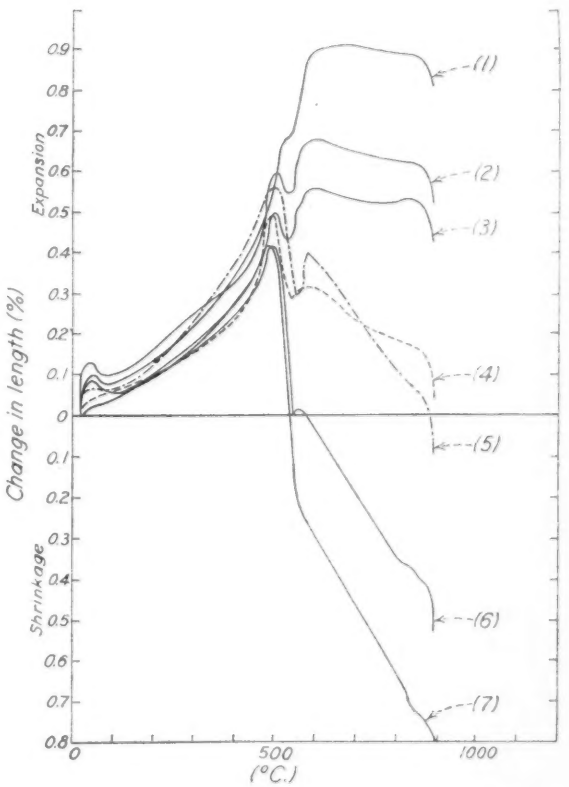

FIG. 8.—Change in length of ball clays during initial heating.

with ultimate strengths. The correlation between fired strength and porosity, under ideal conditions, is fair but cannot be relied upon. The authors have found no record of attempts to correlate ultimate strengths with permeabilities.

Data published by Sortwell[2] shows the variation that may be expected in bodies containing the same quantity of different ball clays. The vitreous china body contained 7½% of ball clay, and the modulus of rupture of the fired bodies varied from about 5500 to 8100 lb. per sq. in., depending merely on the kind of ball clay used. Similar variations were noted in a semiporcelain body. The strengths of the various bodies have been plotted against their corresponding porosities in Fig. 6. Although no perfect correlation was expected, such a plot serves to show how the bonding effect of a given ball clay compares with other ball clays.

The changes in length during the initial heating below 900°C., although small compared to those at higher temperatures, are important from the classification standpoint. Typical length-change curves of ball clays, shown in Figs. 7 and 8, are important because they seem to indicate the behavior of the clays at high temperatures. For example, clay No. 7 has firing and fired properties which border those of sedimentary kaolins. There is a slow gradation in these clays to clay No. 1, which is a typical, early vitrifying, English ball clay. These curves are indicative of mineralogical composition.

Geller and Bunting[3] have shown the influence of mineral composition on length changes occurring during initial heating. Their data showing the effect of muscovite, muscovite and kaolin, and muscovite and ball clay are given in Fig. 9.

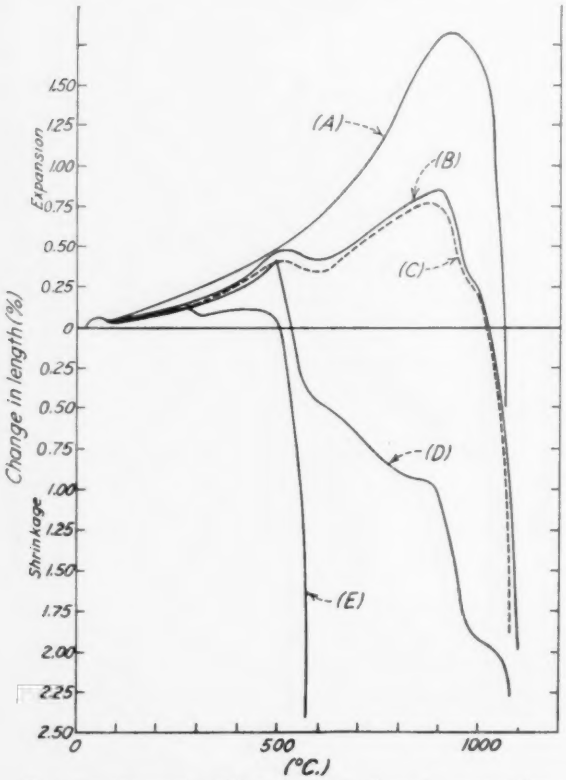

FIG. 9.—Example of influence of mineral composition on length changes; *curves:* (*A*) muscovite; (*B*) 7 kaolin plus 3 muscovite; (*C*) 8 ball clay plus 2 muscovite; (*D*) Zettlitz kaolin; and (*E*) halloysite (data taken mainly from R. F. Geller and E. N. Bunting, footnote 3).

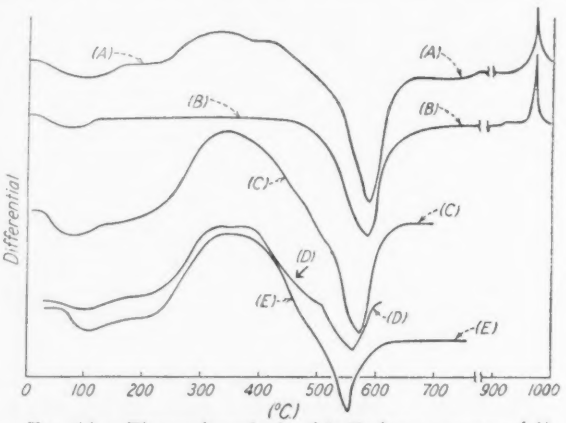

FIG. 10.—Thermal analysis of ball clays; *curves:* (*A*) Tenn. No. 5; (*B*) Tenn. No. 7; (*C*) J. and P. No. 9; (*D*) Ky. No. 12; and (*E*) Ky. Old Mine No. 4.

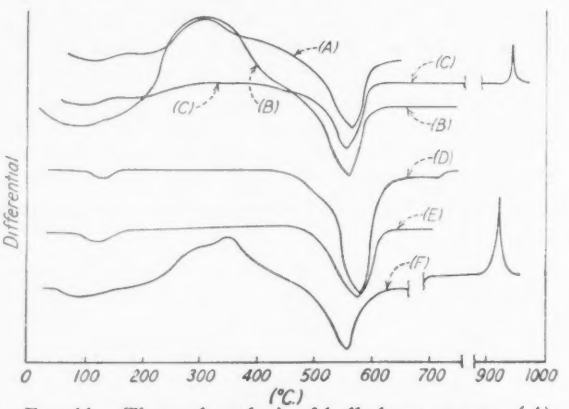

FIG. 11.—Thermal analysis of ball clays; *curves:* (*A*) M. and M. English; (*B*) Whiteway English; (*C*) Dorset; (*D*) Tenn. No. 1; (*E*) J. and P. No. 11; and (*F*) Scott black.

Several examples of variations in ball clays are shown by the thermal analysis curves in Figs. 10 and 11. This type of data is valuable in revealing mineralogical composition, which, in turn, indicates pyrochemical behavior. Differences in the combustible matter in the different clays are clearly shown. Clays low in organic matter, such as Tennessee No. 1, J. and P. No. 11, and Tennessee No. 7, show practically no evolution of heat between room temperature and about 600°C., whereas several of the other clays show considerable evolution of heat.

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[2] H. H. Sortwell, "Bonding Effect of Ball Clays in Fired Bodies," *Jour. Amer. Ceram. Soc.*, **7** [2] 75–81 (1924).

[3] R. F. Geller and E. N. Bunting, "Length Changes of Whiteware Clays and Bodies During Initial Heating, with Supplementary Data on Mica," *Jour. Research Nat. Bur. Standards*, **25** [1] 15–40 (1940); R.P. 1311; *Ceram. Abs.*, **19** [11] 266 (1940).

Symposium on "Testing and Classification of Ball Clays"—General Considerations

TESTING WHITEWARE CLAYS*

By Hewitt Wilson and Herschel Hixon†

Abstract

A group of whiteware clays was given improved, conventional ceramic tests. Round bars were extruded from a small vacuum auger machine. Volume was determined by the submerged weight-in-mercury principle, and bonding strength was indicated by the changes in properties on the addition of potter's flint in 20% intervals up to 80%. Comparative charts, showing curves of controlled water of plasticity, pore water, dry and fired transverse strength, volume shrinkage, and apparent porosity, give patterns which indicate the characteristics of the clays. Suggestions are made for improving standard clay tests.

I. Introduction

In the theoretical studies of clays during the past fifteen years, the practical "proof of the pudding" tests have been neglected. The extremely important and fundamental research in the fields of base-exchange, hydrogen-ion, particle-sizing, and clay-mineral studies adds to our accessory knowledge and helps answer the question of why clays behave as they do and possess the idiosyncrasies of human beings. Clays and human beings belong to general groups, which, when studied carefully, show many individual traits. Both groups show the results of many variable hereditary and environmental influences, as both have been derived by changes from ancestral stock and express the synthesis of many factors. The best method for the evaluation of either group is to study its behavior under working conditions.

The best and final test of an unknown clay is to study it in full-sized batches in regular operation. The next best test is a test which uses full-sized specimens in regular operation; the third uses smaller or sample specimens in regular operation; the fourth is a series of simulative service tests with laboratory equipment and test kilns. The worst tests are those which are indirect, such as judging the fired color, plastic working properties, and P.C.E. from chemical analysis.

Of interest at the present time are the simulative service tests commonly made in the ceramic laboratories of the country, which have been neglected, collectively at least, since 1928. This paper is a plea for renewed activity in revising and devising improved tests for clays of the whiteware type.

The U. S. Bureau of Mines, in its study of raw materials and methods of their beneficiation, maintains a clay team at the Southern Experiment Station, Tuscaloosa, Alabama, which classifies and purifies clays and devises simple and detailed tests for all uses. At Norris, Tennessee, the Electrotechnical Laboratory staff has continued the studies on whiteware clays which were started by the Tennessee Valley Authority. Before the results of electrical or other beneficiation methods can be accurately gauged, the original properties must be known.

* Received August 31, 1942.

† The authors are, respectively, supervising engineer and assistant technical and scientific aide, Electrotechnical Laboratory, Bureau of Mines, U. S. Department of Interior, Norris, Tenn. This paper is published by permission of the Director of the Bureau of Mines, and the work has been done in cooperation with the Tennessee Valley Authority.

The subject of accurate clay testing suggests numerous questions, including the following: (1) Can a given operator check his results within the limits of accuracy of Portland cement testing or chemical analysis? (2) Can different laboratories check each other? (3) What is the minimum number of essential properties needed for the practical evaluation of a clay? (4) The Standard Test Methods have been used since 1928, but where are the numerical specifications for a ball or china clay? (5) Is it possible to devise accurate specifications for clay groups whose definitions are vague and nebulous? (6) Is it better to forsake the attempt at accurate terminology and let each clay stand on its own merits as shown by a few simple but accurately made tests?

Clays have inherent variables which result from their geologic history and subsequent treatment which affect their working properties, including (1) particle size (example: No-Karb coarse fraction compared with the paper-clay fines that have been removed by the centrifuge), (2) degree of dispersion (affected by the anamorphic activity prior to mining or the severity of the mechanical dispersion during preparation, assisted perhaps by electrolytic dispersion or retarded by coagulation), (3) accessory constituents and their magnitude, including quartz, carbon, gibbsite, mica, etc., (4) type of predominating mineral, such as kaolinite or montmorillonite, and (5) character of the particle surface and the ion absorbed thereon.

These inherent properties affect (*a*) the water content required, (*b*) shrinkage, (*c*) pore space, (*d*) strength, and (*e*) resistance to cracking.

Correlations can be made between the preceding causes and effects in a general fashion. The correlation is better if a single type of a general class (Georgia kaolin, for example) is studied. But for tests covering all of the whiteware clays, it has been impossible to obtain mathematical comparisons with such a large number of coacting variables for all of the different methods of molding different sizes and shapes of products.

New variables have been added by the introduction of new minerals to whiteware, including pyrophyllite, talc, white-firing bentonites, montmorillonite, magnesium bentonite (hectorite), mullite, andalusite, dumortierite, kyanite, topaz, zirconia, zircon, titania, cordierite, and synthetic minerals. New minerals will be added continuously to whiteware bodies for specific purposes. When the natural rock or mineral cannot be found, synthetic equivalents will be produced.

II. Methods of Testing and Apparatus

Standard tests or their modifications have been made on white-firing clays for several years at Norris by the same operator. Changes and improvements in technique and apparatus have caused some variation in the uniformity of numerical results. Recently, an attempt has been made to correlate these tests and to note the correlation, if any, between different types of clays as judged by shrinkage, strength, and pore space tests which are apparently simple but are difficult to control with accuracy. Only the new methods and apparatus which differ from the Standard Test Methods of 1928 will be described.

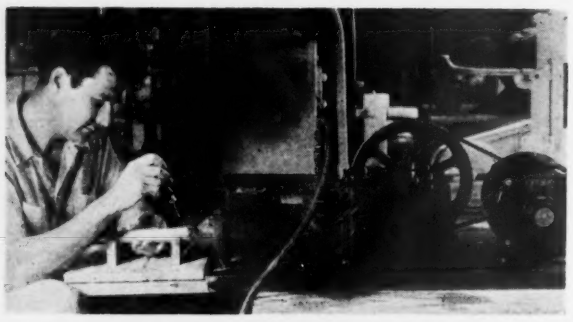


FIG. 1.—Davis Brown vacuum auger machine in operation.

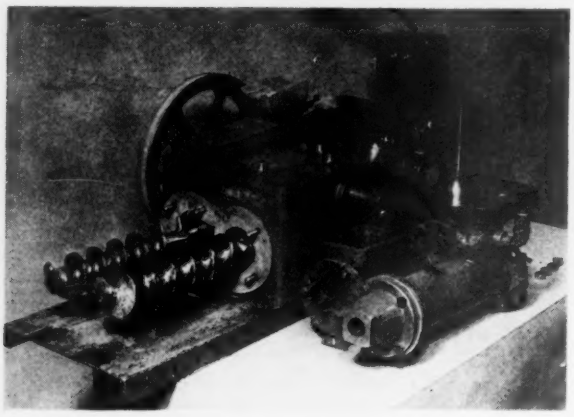


FIG. 2.—Davis Brown vacuum auger open for cleaning.

(1) Grinding and Sizing

The object was to obtain the greatest dispersion without the addition of electrolytes and with the common equipment available to the potter.

Soft kaolins that disintegrated readily to 150 mesh in a trial blunging test were ground to pass only a 20-mesh sieve. Dried ball clays and the harder indurated types were crushed and ground dry in the ball mill to pass 150 mesh.

(2) Flint Additions

The Standard Test Methods require standard Ottawa sand of 20 to 30 mesh for dry transverse strength. These test specimens cannot be used for firing because of the weakness produced by the expansion of the coarse quartz particles. Ball-clay operators have adopted generally the use of 50% potter's flint, but no specifications have been made for the flint. The flint used in the following tests was derived from the pegmatites of North Carolina and contained a small amount of feldspar. The screen analysis gave 1.1% 100 to 200 mesh and 6.0% between 200 and 325 mesh. Distinct coherence was found at cone 12. Purer quartz "flints" should be used for standard tests. Zero, 20, 40, 60, 80, and 100% flint substitutions were made.

(3) Tempering

Flint-clay bodies were weighed, mixed by hand-screening three times through a 20-mesh sieve, and tempered with the weighed portion of water in a bladed machine of the dough-mixer type. Each prepared batch was kept at least overnight before molding.

(4) Test Bars

Round test bars, $1^1/_8$ in. in diameter, were extruded from a table-sized Davis Brown vacuum auger machine (Figs. 1 and 2) equipped with a grid behind the die to reduce the lamination strains. The round test bar used by MacMichael[1] in 1912 eliminated the 90-degree edges, concave faces, and irregular bearing face, permitted warped bars to make a better contact with the bearing knives, and required but a single diameter measurement for use in the following simple formula for transverse strength:

$$\text{Transverse strength (lb. per sq. in.)} = \frac{2.54Pl}{d^3}.$$

The new mercury balance volumeter was used[2] in the most recent tests for volume determinations.

(5) Firing

All firings were made in Globar electric laboratory periodic kilns to cone 12 down, 13[2] heated under the best oxidizing conditions. Over a period of three years, some variation in uniformity was found, principally because the bars were set too close to the cold door.

(6) Tempering Water

It was soon found that unless the water content was controlled for a given series, the dry shrinkage and pore space were irregular. In the later trials, therefore, the maximum and minimum water contents for the all-clay and all-flint bodies were determined, and the water contents of the intermediate members were calculated from the averages of the end members. A tendency to use lower water contents for the higher flint bodies than those calculated was noted. The ranges of water contents were more limited by the requirements of the vacuum auger than by hand-molding.

III. Typical Example

Figure 3 shows the condensed data for a typical domestic ball clay from the Kentucky Clay Mining Company. Drying shrinkage is not indicated by a curve but by the vertical distance (per cent shrinkage water) between points on the water-of-plasticity (W.P.) curve and the pore water curve (P.W.). As the dry properties are modified by

[1] R. F. MacMichael, "Testing of Clay," *Trans. Amer. Ceram. Soc.*, **17**, 639–59 (1915); p. 651.

[2] Sidney Speil and Hewitt Wilson, "An Improved Mercury Balance Volumeter," *Jour. Amer. Ceram. Soc.*, **25** [10] 275–77 (June, 1942).

variations in tempering water, it is preferable to have the water of plasticities on the chart for direct comparison. The dry transverse strengths (D.T.S.) are shown by the dash line. After a little experience with standard curves of this or similar styles, the type of clay can be identified for rough classification by the pattern. The ratios of vertical lines *a* and *b* are also significant; *a* represents the pore water for the 80 to 20 clay-flint mixture, and *b* represents the dry strength for the 40 to 60 clay-flint body. This peculiar selection was made after the present series of thirty-four clays had been tested to select the highest representative value of pore space and strength which

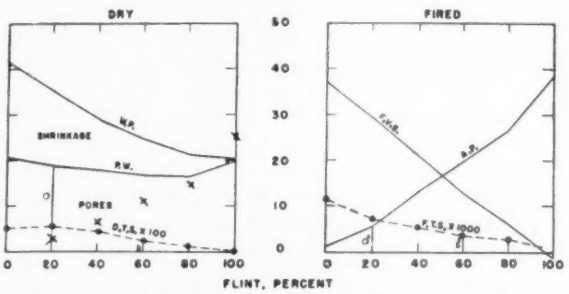


FIG. 3.—Plastic-dry and cone 12 fired data of a ball clay-flint series. W.P., water of plasticity; P.W., pore water; D.T.S., dry transverse strength; F.V.S., fired volume shrinkage; A.P., apparent porosity; F.T.S., fired transverse strength.

could be duplicated with accuracy and freedom from cracking. Twenty per cent of flint increased the safety for porosity measurements for many ball clays, especially those clays containing bentonitic minerals, but it was necessary to use 60% of flint to avoid the strength irregularities caused by cracking.

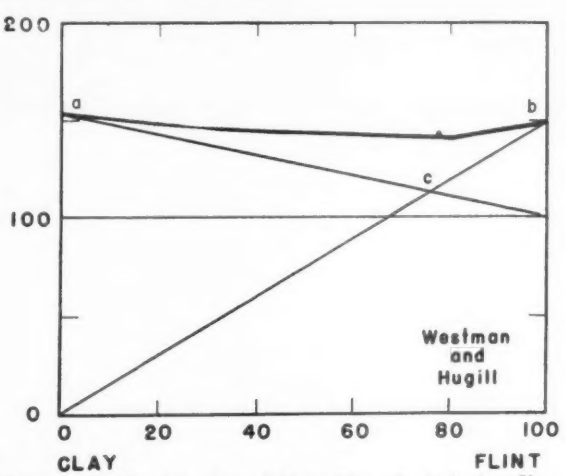


FIG. 4.—Indication of particle packing of a ball clay-flint mixture.

The pore water curve, which corresponds to a per cent absorption curve, as it is a factor of the dry weight, shows a droop which corresponds to that in the W.P. curve. The minimum is near 80% of flint. This deflection is similar to that calculated by Westman and Hugill,[3] but as recalculated to their basis as shown in Fig. 4, the sag in line *ab* is rather small compared to the maximum, *c*, which is the theoretical minimum when a large ratio between the particle sizes of the two end components exists. The small reduction indicates an incomplete packing of the smaller clay particles with the coarser flint particles.

Fired volume shrinkage (F.V.S.), apparent porosity (A.P.), and transverse strength (F.T.S.) were used to indicate the fired properties of each clay. The pattern of these curves also indicates the clay type, although the type may not correspond to that selected from the dry data. The porosity-strength ratios, a'/b', are also important for correlation.

When heated to cone 12, the pore space (per cent weight basis) decreased to the per cent absorption values shown by the line, *X*, in Fig. 3. The all-flint sample showed an expansion of 1.4% and an increased absorption.

Charts similar to Fig. 3 have been plotted for thirty-four clays, and the tests are being continued. When compared, they showed a wide variation in properties with many types of variations. It was then necessary to choose one or two important tests that illustrate essential and distinguishing properties.

IV. Dry Strength, Shrinkage, and Pore Space

In the plastic-to-dry condition, bonding strength is probably the most distinguishing factor that can be tested easily and for which a simple test is already in common use. Although directly indicating bonding strength in the dry state, dry transverse strength only indirectly checks the same property for the plastic condition. Pottery molding, however, includes casting, jiggering, dry pressing, and plastic extrusion, and simulative service tests are necessary to more clearly distinguish the special attributes needed for each process.

Shrinkage is the second important plastic-to-dry property, but inasmuch as it varies widely with the water of plasticity, it has been made secondary in this paper to the dry pore space which has shown less variation with tempering water.

The pore water of the 80 to 20 clay-flint mixture was chosen as the second attribute, as it (1) showed a fairly uniform change from the least plastic clays to the strongest clays, (2) corresponded to shrinkage changes, and (3) is related to the porosity determinations used in the fired correlative studies. It would have been simpler to use

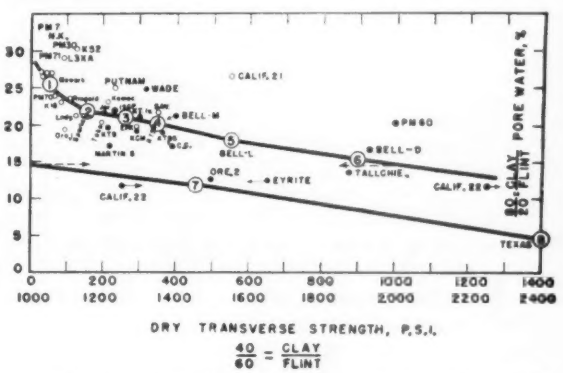


FIG. 5.—Relation between dry pore space and dry strength for whiteware clays.

[3] A. E. R. Westman and H. R. Hugill, "Packing of Particles," *Jour. Amer. Ceram. Soc.*, **13** [10] 767–79 (1930).

either the shrinkage or pore space of a single mixture, such as a 40 to 60 clay-flint mixture, but in this case the variation between clays was more irregular and the differences were less. As more clays are tested and test methods are improved, other data with better correlation may be found.

Figure 5 shows the relation between pore water (per cent dry pore space on the dry weight basis) and dry transverse strength.

Group 1 consists of (1) the weakest kaolins with the largest pore volumes and includes No-Karb (N.K.), a coarse-grained, Georgia clay from which the fine sizes have been removed, (2) a number of English china clays, P. M. 7, 30, 70, and 71, and (3) the Newark kaolin. Their strengths were all below 100 lb. per sq. in. for a 40 to 60 clay-flint mixture.

Group 2 is the average of kaolins having intermediate strength and includes two well-known North Carolina kaolins, Sparks and Lunday, as well as Ringold, the little-known West Tennessee kaolin now under investigation by the Tennessee Valley Authority for alumina extraction. This occurs between the far more plastic Tennessee and Kentucky ball clays and the Tako kaolin of northwestern Alabama. Oregon 1 is a flintlike kaolin between groups 1 and 2.

Group 3, with strengths between 200 and 300 lb. per sq. in., includes the weakest domestic ball clays, a Florida plastic kaolin, and Kamec, a strong North Carolina kaolin. Group 4 has stronger ball clays and a strong Georgia kaolin. Groups 5 and 6 show still stronger ball clays, including those to which bentonite has been added by nature. Groups 7 and 8 are clearly montmorillonites or Eyrite, hectorite or the so-called magnesium bentonite.

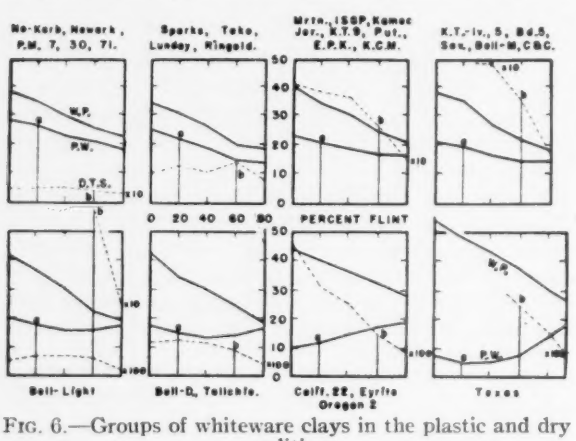


FIG. 6.—Groups of whiteware clays in the plastic and dry condition.

Group 8 is the white-firing, low-refractory Texas montmorillonite which is now being developed commercially. A small percentage of this gives a marked increase in plastic toughness and dry strength. California 22 is a low-fusion clay of high strength, whereas California 21 is more of the kaolin type, giving an unusually high pore space for its dry strength.

Figure 6 shows the plastic and dry charts of the eight groups. The water-of-plasticity, plastic, and dry strength curves show an irregular rise from groups 1 to 8. The shrinkage area between the two curves gives a more regular increase, but is not so uniform as the pore space decrease under the pore water curve. The use of the single pore water percentage, *a*, of the 80 to 20 clay-flint mixture would simplify operation and calculations. Dry transverse strength increases with the group numbers, groups 6, 7, and 8 having strength values 100 times the charted data. Strengths of samples containing more than 40% of clay were lower in most cases than indicated by that portion of the curves which contains 40 and 20% of clay. The data for the high clay mixtures were also irregular and indicated irregular weakness from cracking.

V. Bentonitic Clays

Several clays with data above the average behaved as though they contained a small amount of powerful bonding films that did not fill the pores, but, in general, dry strength varied as the density and inversely as the pore space. The extremely high strength of the bentonitic types is shown by the 6 to 1 ratio and by the greater strengths of these little-used minerals compared with the common type of domestic ball clay. Small amounts of these minerals added to kaolins would raise their strength to the ball-clay

TABLE I

EFFECT OF TEXAS MONTMORILLONITE ON NO-KARB KAOLIN (NO FLINT ADDITION)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	100	33.0	28.7	4.3	6.7	100
10	90	35.7	27.3	8.4	13.1	694
20	80	38.5	23.9	14.6	23.8	1830
30	70	40.9	19.7	21.2	36.9	2530
100	0	65.0	8.0	57.0	92.9	*

* Bad cracking.

Column (1), Texas montmorillonite; (2) No-Karb kaolin; (3) water of plasticity (%); (4) pore water (%); (5) shrinkage water (%); (6) volume shrinkage (%); (7) dry transverse strength (lb./sq. in.).

values; e.g., Table I shows the changes found by substituting 10, 20, and 30% of Texas montmorillonite of Group 8 for the No-Karb, coarse kaolin of Group 1, with no addition of flint. The addition of montmorillonite to the more plastic kaolins gives even stronger results.

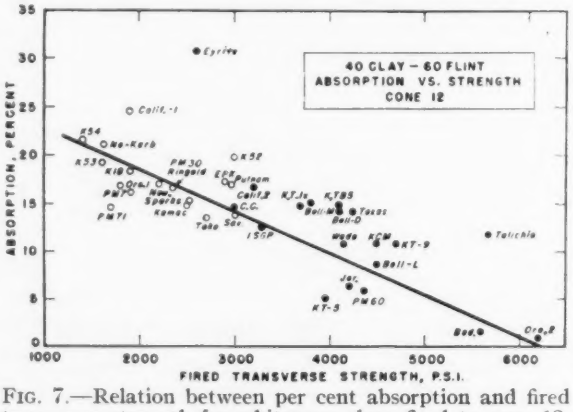


FIG. 7.—Relation between per cent absorption and fired transverse strength for whiteware clays fired to cone 12.

VI. Correlation of Fired Data

A greater choice was found with the fired data in making the correlation between pore space and strength. Either per cent apparent porosity or per cent absorption can be

used for pore space, and these show enough range with the 40 to 60 clay-flint mixtures to indicate different vitrification activities during firing. The absorption versus strength data for the 40 to 60 mixtures is shown in Fig. 7.

The grouping differs from that of the plastic and dry data. California 21 showed more of the kaolin characteristics by falling back from the ball-clay strengths; it still had a high porosity, however, at cone 12 (probably due in this case to overfiring). The excessive pore space of the Tallahatchie, Mississippi, ball clay was due to slight bloating. The Texas montmorillonite was also overfired and fell back to the ball-clay group with high pore space, and Eyrite was badly displaced; an Oregon bentonite, which without flint overfired at cone 6, was found, however, to be the strongest clay with minimum absorption. Jernigan ball clay changed its relative position from a weak, dry ball clay to a much stronger fired body because of its flux content.

In general, less overlapping of ball and china clays was found from the firing data than by the use of the plastic and dry data, and the modifying effect of impurities and fluxes that survived oxidation replaced the action of organic influences on the dry strength.

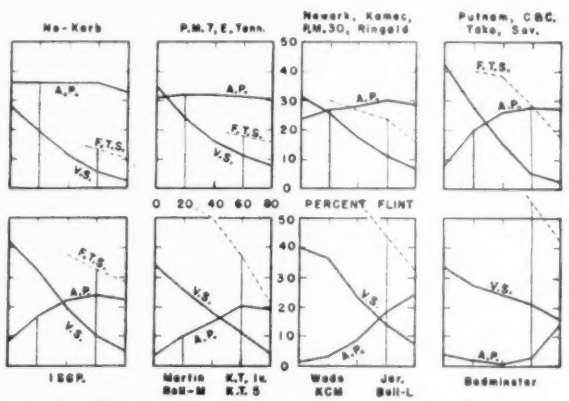


FIG. 8.—Groups of whiteware clays in the fired state (cone 12).

Figure 8 shows the porosity, strength, and shrinkage of eight typical clays or groups. The groups from No-Karb to Bedminster show an interesting porosity-shrinkage change of pattern with the porosity curve dominating the kaolin patterns, but with the shrinkage curve superior in the highly vitrified ball-clay charts. The ratio of the vertical lines, *a* and *b*, for porosity and strength changes continuously.

VII. Conclusions

The foregoing data indicate that (1) considerable study is necessary to obtain an adequate and accurate system of clay testing, (2) group testing of variable clay-flint mixtures, controlled water content, and separate batch mixing is an excellent check method for test correlation and produces characteristic, individualistic patterns for each clay, (3) the man-made boundary between kaolins and ball clays is an artificial fence with more mingling at the fence in the plastic-dry state than in the fired state (the geographic gradation of ball and china clays is also found), and (4) classifications of clays must be made separately for the plastic-dry and for the fired state.

The following suggestions are made for improving standard clay tests: (1) standard clay samples of various types and a standard flint should be selected, (2) the standard clays should be check-tested by numerous laboratories, (3) data should be interchanged to note the variation among different operators, (4) the work should be done by trained operators who will check and recheck their own work, (5) a standard sensitive clay should be placed in each firing for a check on the fired strength (this is believed to be more accurate than firing to the same temperature or cone without an accurate check on the strength itself), (6) a porosimeter should be used for an accurate measurement of dry pore space instead of the usual water-of-plasticity-minus-shrinkage-water method, (7) pore space versus strength should be used to classify clays, with strength as the more important property, and (8) the triangular relationship between pore space, shrinkage, and strength should be studied further.

A SURE INVESTMENT

With High Income Return

For Each Dollar Paid by Members, Personal and Corporation, THE AMERICAN CERAMIC SOCIETY in 1941 Expended One Dollar and Sixty Cents.

Forty-Fifth Annual Meeting

Hotel William Penn, Pittsburgh, Pa.

Week of April 18, 1943

ACTIVITIES OF THE SOCIETY

NEW MEMBERS FOR OCTOBER

Corporation

AMERICAN WINDOW GLASS CO., A. S. Crandon (voter), 16th Floor, Farmers Bank Bldg., Pittsburgh, Pa.

DIAMOND ALKALI CO., Fred W. Fraley (voter), 535 Smithfield St., Pittsburgh, Pa.

OWENS-ILLINOIS GLASS CO., E. W. Summers (voter), General Engineering Dept., Alton, Ill.

WALSH WALSH, JOHN, LTD., W. G. Riley (voter), Soho & Vesta Glassworks, Birmingham, 18, England.

WILLSON PRODUCTS, INC., Thomas A. Willson (voter), Box 622, Reading, Pa.

Personal

BOTFIELD, GEORGE B., 210 Valley Road, Merion Station, Pa.; assistant vice-president, Botfield Refractories Co.

BOWDEN, JAMES J., 2538 E. Market St., Warren, Ohio; chief metallurgist, Republic Steel Corp.

CROUCH, GUINEVERE E., Montana School of Mines, Butte, Montana; librarian.

FROMER, CHARLES H., Park Ave., R. D. 1, Library, Pa.; superintendent, Hays Works, Harbison-Walker Refractories Co.

MORRISON, JOSEPH P., R.D. 1, Charleroi, Pa.; physicist, Corning Glass Works.

OLNEY, WILSON, Room 809A, 89 Broad St., Boston, Mass.; district representative, North American Refractories Co.

ROBITSCHEK, JOSEF M., Box 353, Tallmadge, Ohio; research engineer, U. S. Stoneware Co., Akron, Ohio.

SWANK, C. FERGUSON, 1105 Fidelity Bldg., Cleveland, Ohio; district manager, Hiram Swank's Sons.

WAINER, EUGENE, 2654 Whirlpool St., Niagara Falls, N. Y.; research associate, Titanium Alloy Mfg. Co.

Student

Missouri School of Mines and Metallurgy: F. G. MERTENS.

New York State College of Ceramics: WILLIAM KERSHNER.

Pennsylvania State College: JOSEPH FREEMAN AND NEIL I. KANTOR.

University of Texas: DAVID W. GOLDSMITH, JAMES J. HALBOUTY, HARVEY Z. HURLBURT, HOWARD H. HURMENCE, MELVIN A. NOBLES, JOHN B. OTTO, JR., SAMUEL SUTHERLAND, JR., AND MERYL D. WILLIAMS.

MEMBERSHIP WORKERS' RECORD

Corporation

F. C. Flint	1	J. W. Wright	1
		Office 3	

Personal

R. E. Birch	3	C. L. Thompson	1
E. C. Petrie	1	Office	4

Student

E. C. Henry	1	M. E. Holmes	1
P. G. Herold	1	F. K. Pence	8
		W. A. Weyl 1	
		Grand Total	**26**

STUDENT MEMBERSHIP IN THE AMERICAN CERAMIC SOCIETY

$5 while in school and for one year after leaving school

ROSTER CHANGES FOR OCTOBER*

Personal

BARTELS, KEITH D., 948 N. Negley Ave., Pittsburgh, Pa. (Chicago, Ill.)

BLANCHARD, M. KENNETH, A. O. Smith Corp., 3533 N. 27th St., Milwaukee, Wis. (Urbana, Ill.)

COLEMAN, MIDSHIPMAN ROBERT L., Section 41, U.S.S. *Prairie State*, New York, N. Y. (Chicago, Ill.)

EMLEY, WILLIAM S., 303 Englewood Ave., New Castle, Pa. (New Brunswick, N. J.)

HUMMEL, ROY, B. G. Corp., Broad Ave. & Shaler Blvd., Ridgefield, N. J. (New York, N. Y.)

LAWLER, W. J., Aluminum Club, New Kensington, Pa. (Rolla, Mo.)

LAWRENCE, WILLIS G., 4 Circle Road, Suffern, N. Y. (Cambridge, Mass.)

MERZ, GEORGE, Magnesita S. A., Rio de Janeiro, Brazil, South America (Buenos Aires, Argentina, South America)

MUELLER, CAPT. JAMES I., Headquarters, Engineer Amphibian Command, Camp Edwards, Mass. (Ft. Leonard Wood, Mo.)

NETTER, WILLIAM S., 808 Adee Ave., Bronx, N. Y. (Aberdeen, Md.)

NEWMAN, ROBERT W., 1495 Filmore Ave., Buffalo, N. Y (Cleveland, Ohio)

O'MEARA, ROBERT G., 1400 Elm St., Rolla, Mo. (Tuscaloosa, Ala.)

SARANDRIA, JOSEPH A., c/o George Daley, 318 Classon Ave., Brooklyn, N. Y. (Chicago, Ill.)

SHATTUCK, LUCILLE, 230 Seville Way, San Mateo, Calif. (Santa Monica, Calif.)

SMITH, J. TALBOT, c/o Walter E. Smith, 33 S. Valley Ave., Vineland, N. J. (Chicago Heights, Ill.)

SNYDER, ERNEST B., Apt. 15, 716 Sixth Ave., Bethlehem, Pa. (Columbus, Ohio)

THOMAS, SAMUEL L., JR., 234 Walnut St., Westfield, N. J. (Chicago, Ill.)

* Address in parentheses is former address.

MICHIGAN-NORTHWESTERN OHIO SECTION

The initial autumn meeting of the Michigan-Northwestern Ohio Section was held September 25 at the Rackham Memorial in Detroit, Mich.

The guest speaker was T. A. Boyd of the General Motors Corporation, who gave an extremely interesting and timely talk on "Oil and Turmoil," with a few sidelights thrown in on aviation gasoline and synthetic rubber.

The matter of furnishing ceramic textbooks for the library of the Engineering Society of Detroit was placed in the hands of a committee appointed by J. F. Quirk, president of the Section.

The second meeting of the Section was held November 6 in Detroit, the city in which all meetings for the ensuing year will be held.

—W. V. BLAKE, *Secretary-Treasurer*

PITTSBURGH SECTION

The Pittsburgh Section held its first meeting of the 1942–1943 season on October 13, 1942, at Mellon Institute, Pittsburgh, Pa.

C. E. Hawke, general sales manager, Refractories Div., Carborundum Co., Perth Amboy, N. J., spoke on "Superrefractories Made from Electric Furnace Products, Their Development and Application."

—R. M. SHREMP, *Secretary*

CERAMIC EDUCATIONAL COUNCIL PAGE

ATTENTION CERAMIC INDUSTRIES !

THE MANPOWER SITUATION IN CERAMICS

CRITICAL SHORTAGE OF CERAMIC TECHNICAL MEN

To determine the total number of college seniors at present enrolled in curricula in ceramic engineering and technology and glass technology, a survey was made of all institutions throughout the United States, with the following results:

Total senior enrollment	135
Number of seniors who will enter military or naval service upon graduation	64
Number of seniors available upon graduation for technical work in American industry	71*
Total number of graduate students	Less than 10

* Some of these men have already accepted offers of jobs; others are considering enlistment.

Nearly all ceramic departments have "speeded up" to permit earlier graduation and thus aid the industries. Dates of graduation are as follows:

	Date of Graduation	School
1942	December	Pennsylvania State College
1943	January	Missouri School of Mines and Metallurgy
	February	Georgia School of Technology
		University of Illinois
	March	University of North Carolina
		Iowa State College
		Virginia Polytechnic Institute
	April	Ohio State University
	May	New York State College of Ceramics
		Rutgers University
	June	Georgia School of Technology
		University of Illinois
		University of Washington

It will be obvious from the foregoing evidence that companies desiring ceramic graduates should take immediate steps to contact them. The number of men available is extremely limited.

—NELSON W. TAYLOR, Chairman
Ceramic Educational Council

TEAM SOLIDARITY

of

Rugged Individuals

makes

The American Ceramic Society, Inc.,

Effective in

Ceramic Arts, Science, and Technology

PAID MEMBERSHIP AND SUBSCRIPTION RECORD

Date of Record	Members Paid Personal	Members Paid Corporation	Deferred	Subscriptions	Monthly Sales	Total Circulation
December 21, 1941	2029	257	37	609	220	3152
February 21, 1942	2083	255	34	605	220	3197
September 21, 1942	2002	261	20	449	220	2952
October 21, 1942	2031	268	21	450	220	2990
A Year Ago	1980	254	43	613	220	3110

Note that increase of fifty-one (51) persons and fourteen (14) corporations over the record of one year ago—a gathering strength for postwar security.

INSTITUTE OF CERAMIC ENGINEERS

President: H. M. KRANER, Bethlehem Steel Co., Bethlehem, Pa.
Vice-President: H. B. DUBOIS, Consolidated Feldspar Corp., Trenton, N. J.
Secretary: H. G. SCHURECHT, New York State College of Ceramics, Alfred, N. Y.
Past-President: E. H. FRITZ, Stupakoff Ceramic & Mfg. Co., Latrobe, Pa.
Trustee Representative: H. G. WOLFRAM, Porcelain Enamel & Mfg. Co., Baltimore, Md.

WHAT THE COMMITTEE ON ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT HAS DONE AND IS DOING

It required a world war to bring to ceramic engineers the full realization that although their branch of engineering is one of the oldest outside of the Founders' Societies it is one of the least known in the engineering field. It has been somewhat of a shock to many to find that the Selective Service System, the Army, and the Navy have refused to recognize that ceramic engineering, except in a few cases, has any place in the war effort.

It would serve no useful purpose to detail the many reasons for the present situation, but on the fact that for several decades the ceramic engineers had no representative organization can be placed most of the blame.

Although the Institute of Ceramic Engineers has not been organized long enough to bring full national recognition to its members, its officers and committees have made remarkable progress toward that goal.

The program now carried on by the Institute was originated by Keramos, the national professional ceramic engineering fraternity, in 1932 and continued by that organization until 1937, when the Institute was established and took over the work.

To get a complete picture of this program, it is necessary to review briefly the preliminary work done by Keramos.

Early in the last decade, the Engineers' Council for Professional Development was organized by the Founders' Societies and made plans to examine and accredit all departments of engineering in the educational institutions of the country. Keramos, the only national organization composed entirely of ceramic engineers, undertook to represent them in an effort to obtain recognition as a separate professional branch of engineering. At the time, the granting of such recognition appeared very questionable.

The Executive Committee of Keramos organized itself into a Committee on E.C.P.D. and made contact with the officers and members of the Council. After a considerable effort, in which it was given assistance by a committee appointed by The American Ceramic Society, this Committee succeeded in convincing the E.C.P.D. that ceramic engineering was a separate and distinct branch of engineering and granted it recognition as such. It was thus placed on the same independent footing as civil, mining, mechanical, electrical, and other branches of engineering.

Until the Institute was organized, Keramos was called upon to appoint ceramic engineers as representatives on the E.C.P.D. committees that audited the departments for accrediting. Since then, the Institute has performed this function.

That there has been close cooperation between E.C.P.D., the Committee, and the departments of ceramic engineering is evidenced by the fact that with the accrediting of the Department of Ceramic Engineering at the Georgia School of Technology this year every eligible ceramic engineering department in the country has been accredited. Ceramic engineering thus becomes the first branch of engineering to have its departments accredited one hundred per cent.

In addition to its work in connection with the accrediting program, the Committee has made strenuous efforts to obtain membership for the Institute on the E.C.P.D. In this it has been unsuccessful. It now, however, has representation through the appointment to the Council of A. F. Greaves-Walker by the American Institute of Mining and Metallurgical Engineers.

Reference should be made to the whole-hearted assistance and support given to the Institute's committees by the A.I.M.M.E. The success in obtaining the recognition of E.C.P.D. was due largely to the friendly help of this organization, one of the original members of the Founders' Societies and the E.C.P.D.

When the efforts of the A.I.M.M.E. to assist the Institute in obtaining membership on E.C.P.D. proved unsuccessful, the organization solved the problem for the time being, at least, by appointing a ceramic engineer as one of its representatives on the Council.

—ARTHUR F. GREAVES-WALKER

EDITOR'S NOTE: This is the first of a series of reports on the work done by the Institute committees since its organization

WINNERS OF OSCAR HOMMEL GOLF TROPHIES

William M. Weathers–Carl J. Uhrmann

William M. Weathers, Pigment Div., International Smelting & Refining Co., Akron, Ohio, for the second time was awarded the Oscar Hommel Trophy at the golf tournament held by the White Wares and Materials and Equipment Divisions at their joint autumn meeting at the Pennsylvania State College, State College, Pa., on September 18.

Carl J. Uhrmann, vice-president of the Imperial Glass Corp., Bellaire, Ohio, was awarded a duplicate trophy at the golf tournament of the Glass Division held at its autumn meeting at the Seaview Country Club, Absecon, N. J., on September 19.

The golf trophies were awarded for the first time at these meetings last year. They are to be given yearly by the O. Hommel Co., Pittsburgh, Pa., in honor of the memory of their late president and founder, Oscar Hommel.

Other winners in the Glass Division tournament are as follows:

Low Net Contest: R. M. CURTS, American Potash & Chemical Corp., New York, N. Y.; prize, carry-all bag.

Special Contest: J. J. MORAN, Kimble Glass Co., Vineland, N. J.; prize, umbrella.

Flag Contest: F. D. PINOTTI, Kimble Glass Co., Vineland, N. J.; prize, dozen golf balls.

Kickers Contest: (1st) I. G. STEWART, Diamond Alkali Co., Pittsburgh, Pa.; (2d) L. G. LOVE, National Lime and Stone Co., Findlay, Ohio; (3d) C. L. CRUIKSHANK, Great Lakes Foundry Sand Co., Detroit, Mich.; (4th) H. T. BROWN, Westinghouse Electric & Mfg. Co., Bloomfield, N. J. Each winner in this group received a sports shirt.

Autumn Meeting Attendance

Refractories Division (Dearborn Inn, Dearborn, Mich., August 28–29)	49
White Wares and Materials and Equipment Divisions	64
Glass Division	65

MEMBERS IN SERVICE*

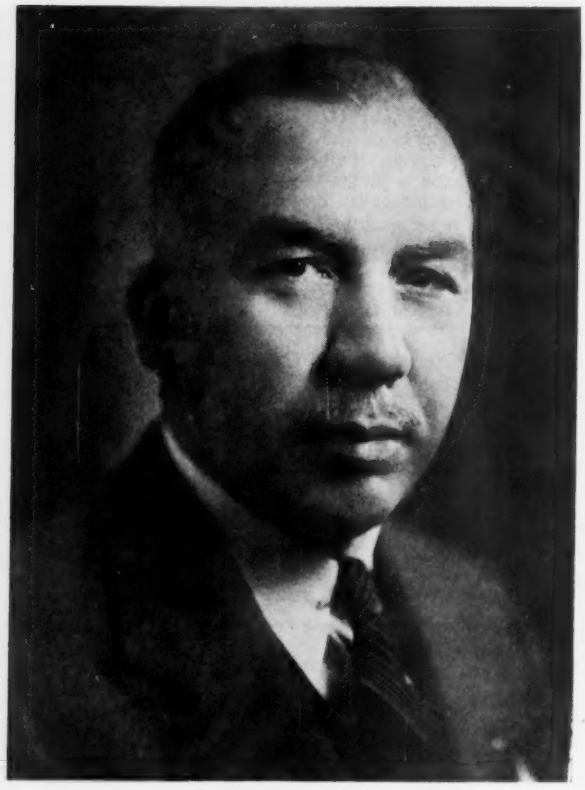
The following members of this Society are in fighting units of war service. There are several in service in Washington not included in this Service Roster. This list is probably not complete, and we would appreciate information on other members.

SIDNEY J. BROOKS, Battelle Memorial Institute, Columbus, Ohio.
MICHAEL W. E. DOYLE, Battelle Memorial Institute, Columbus, Ohio.
W. G. EKDAHL, Pennsylvania State College, State College, Pa.
J. M. FLORENCE, 4556 Aldine St., Philadelphia, Pa.
ELTON S. GAMBLE, J. G. White Engineering Co., Niagara Falls, N. Y.
EDWARD W. GEHRKE, New York State College of Ceramics, Alfred, N. Y.
GLENN HOWATT, General Ceramics & Steatite Co., Keasbey, N. J.
COLLIN HYDE, McLain Fire Brick Co., Wellsville, Ohio.
RALPH V. LAWRENCE, Virginia Polytechnic Institute, Blacksburg, Va.
E. T. MITCHELL, Georgia School of Technology, Atlanta, Ga.
RALPH E. RHODES, JR., Ferro Enamel Corp., Cleveland, Ohio.
FRED. W. SCHROEDER, A. P. Green Fire Brick Co., Mexico, Mo.
R. H. SCHWENDLER, Enamel Products Co., Mentor, Ohio.
WILLIAM D. SPORE, Homer Laughlin China Co., East Liverpool, Ohio.
DONALD K. STEVENS, University of Illinois, Urbana, Ill.
PICKETT TURNER, JR., University of North Carolina, Raleigh, N. C.
RAYMOND C. WOMELDORPH, Virginia Polytechnic Institute, Blacksburg, Va.

* Published monthly, beginning with the September, 1942, *Bulletin*.

WALLACE T. MONTAGUE

Wallace T. Montague has been elected vice-president of the Norton Co., Worcester, Mass.



Wallace T. Montague

Biography

Mr. Montague attended the Worcester public schools and received his Bachelor of Science degree in Mechanical Engineering from the Worcester Polytechnic Institute in 1912.

He has been associated with the Norton Company since 1912 and has served in the following capacities: 1912–1913, in the research laboratory; 1914, in the Sales Department; 1916, head of Sales Engineering Department; 1919, assistant sales manager, Abrasive Division; 1922, assistant sales manager, Machine Division; 1923, sales manager, Machine Division; 1929, assistant general sales manager; 1932, director of sales, Abrasive Products Divisions; 1935, manager of sales planning and development; 1939, assistant vice-president; and September, 1942, vice-president.

Activities and Club Memberships

Mr. Montague is trustee of the Worcester Polytechnic Institute and of the Worcester County Institution for Savings, past-president of the Worcester Chamber of Commerce, chairman of the Board of Directors of the Grinding Wheel Manufacturers' Association, Worcester, Mass., and vice-president of the Special Refractories Association, New York, N. Y.

He is a member of the University Club of Worcester, the Worcester Country Club, the Worcester Club, and the Newcomen Society.

Mr. Montague is married and has a son in the United States Navy and a daughter attending Connecticut College, New London, Conn.

KOPP GLASS, INC., NAMES RESEARCH DIRECTOR

The appointment of Charles E. Leberknight as head of the newly created Department of Research of Kopp Glass, Inc., Swissvale, Pa., has been announced by C. H. Curry, president of the Company. Dr. Leberknight assumed his new duties on October 1.

Before becoming associated with Kopp Glass, Inc., Dr. Leberknight was a member of the Research Department of the Switch and Signal Co., Pittsburgh, Pa. Before that, he served as an instructor in physics at the Carnegie

Institute of Technology, where he was a member of the graduating class of 1926. He took his graduate work at the University of Illinois and at Johns Hopkins University.

Charles E. Leberknight

Kopp Glass, Inc., has been manufacturing railroad, marine, and traffic signal glass and illuminating glassware of all kinds for more than forty years. It was organized in 1901 by the late Nicholas Kopp, who was the discoverer of selenium-red signal glass.

The Company recently ceased to manufacture standard types of incandescent-lighting glassware and is now using its entire engineering, research, and manufacturing facilities to produce technical and industrial glass specialties in which colored and heat-resisting glass and optical design play an important part.

Kopp Glass, Inc., has established a reputation over many years for its ability to meet the specifications of manufacturers, railroads, municipalities, and the U. S. Army and Navy for color and design in technical glass specialties and also in the field of glass which must withstand extreme temperatures and weather variations. In this work it is performing a valuable wartime service to contractors who are filling Army and Navy orders for aviation and airport installations and many other kinds of military equipment.

The newly created Research Department will permit a more intensive study of the physical properties of glass and the possibilities for the further advancement of the science of glassmaking. Dr. Leberknight will devote his entire time to this assignment.

CERAMIC SCHOOL NOTES

UNIVERSITY OF TORONTO

There has been a large increase in the number of first-year engineering students this year; this applies to ceramics as well as to other branches of engineering. Overcrowding, especially in the chemical and mechanical engineering departments, has made necessary some restrictions in the numbers allowed to register in these departments. The registration in ceramics and nonmetallic minerals is as follows: 1st year 19, 2d year 5, 3d year 2, and 4th year 1 (total 27).

Military study and training is compulsory for all students, but an effort is made to maintain the quality of the work in the classroom at a high standard. As a part of this idea, the engineering courses have not been accelerated and the usual school year is adhered to. Our long summer vacation period gives about five months for the student to enter war plants or to take special training in advanced military study. Some of the students, especially those in the early years, also are free to relieve the labor shortage on the farms. The movement now is to place the undergraduate and the graduate where he can contribute most to the war effort.

The Student Engineering Society, which includes all engineering students, has started its winter series of meetings which are held every two weeks. On October 6, the Society was addressed on the subject of plastics by a representative of the General Electric Company.

CERAMICS AT M.I.T.

Several of the graduate students have recently left the Massachusetts Institute of Technology, Cambridge, Mass., to carry out research in the war industries and others have gone directly into the armed services. At present, however, there are five men working for the doctorate in ceramics and a number of others are taking special courses in ceramics.

J. L. Utter, assistant in ceramics, has recently been taken over by an important war development to carry out ceramic research.

Work is continuing on the fundamental study of clays under a grant from the industry. Much important information has been obtained recently on the interparticle water film and the charge on single clay particles. Other research projects are being carried out in the ceramic laboratory directly connected with the war effort.

UNIVERSITY OF PITTSBURGH

Kuan Han Sun, who was post-doctorate fellow in chemistry and who obtained his Ph.D. degree in 1940 with a major in glass technology, is in the Research Laboratory of the Eastman Kodak Co., Rochester, N. Y.

Hurd W. Safford, who obtained his Ph.D. degree in 1941 with a major in glass technology, is teaching chemical microscopy and instrumentation in the Department of Chemistry at the University of Pittsburgh and was recently appointed executive assistant to Alexander Silverman, head of the Department.

Frank Day, Jr., who obtained his Ph.D. degree with a major in glass technology in 1941, is in the Research Laboratory of the Corning Glass Works, Corning, N. Y.

FORTY-FIFTH ANNUAL MEETING
AMERICAN CERAMIC SOCIETY with seven simultaneous Division meetings.
Week of April 18, 1943, William Penn Hotel, Pittsburgh, Pa.

UNIVERSITY OF ILLINOIS

Student Branch News

The Student Branch at the University of Illinois is faced with the problem of losing the majority of its seniors in February, 1943, owing to the accelerated program. For this reason, the annual Pig Roast will be held in December. A meeting will also be held on November 18.

Although the registration for the summer session was low compared with the regular semester, the Student Branch held a very successful picnic on August 5. Twenty-eight persons, including the professors, were in attendance, and a softball game revealed many athletes in this group. The friendly banter and discussion during the picnic supper which followed provided ample opportunity for the students and faculty to become better acquainted.

The first picnic was so successful that a second picnic was held on September 23; both softball and football were played. Thirty-three students and professors made this affair a congenial and enjoyable beginning for the semester's activities.

A fellowship open-house night was held on October 7. As the men entered, they received name cards which were a welcome convenience and helped them all to get acquainted. Professor Hursh, in his capacity as faculty advisor, welcomed the freshmen and discussed some phases of ceramics pertaining to the war effort.

The freshmen and sophomores were divided into groups of two or three, and a senior or junior escorted these groups around the Ceramics Building, where the professors explained some of the apparatus used in the various courses. This tour was climaxed by a "Magic Show" given by Ray Davies. He showed how the viscosity of a slip was changed by stirring. Of course, the electrolyte in which he dipped the stirring rod was a help. Then Mr. McDevitt gave an exhibition of throwing and casting just to prove how easily pottery can be made.

Refreshments, served in the Kiln House, made a welcome end to a most enjoyable evening.

Under the advice of A. I. Andrews and R. K. Hursh, the Student Branch is looking forward with keen anticipation to the events of the coming year.

Officers for 1942–1943

President, F. P. SHONKWILER; *Vice-President*, EARL SMITH; *Treasurer*, JOHN GRAHAM; and *Secretary*, GORDON JOHNSON.

Enameled Kitchenware Swells Scrap Pile

In the program to improve enameled kitchenware, thousands of kitchen utensils have been sent for testing to the University of Illinois from manufacturers in conjunction with the Enamel Utensil Manufacturing Council Fellowship. Over the past two years, many articles have been tested for impact resistance, thermal-shock properties, and acid or solubility resistance.

In conjunction with the all-wide University drive for scrap, a huge pile of these tested enameled kitchen utensils has been gathered together.

A few years ago, enameled articles were not reclaimable for metal scrap. With the shortage of scrap metal becoming increasingly serious, the steel manufacturers have found that by passing enameled articles through immense corrugating rolls most of the porcelain-enamel coating can be pulverized and in that way removed. So today scrap kitchen utensils and other porcelain-enameled ware may go to form the tanks, ships, or armored cars of tomorrow.

UNIVERSITY OF NORTH CAROLINA

The Department of Ceramic Engineering of the University of North Carolina, Raleigh, N. C., was active during the summer months doing its part in the education speed-up program. Approximately 90% of the Department's students returned for the summer, as the normal fall term courses were not to be repeated the following term.

The fall term started on September 25 with the following registrations by classes: seniors (graduation in March, 1943) 9, juniors (graduation in December, 1943) 10, sophomores 10, and freshmen 8.

All departments in the engineering school have smaller freshmen classes than usual except aeronautical engineering, which is abnormally high.

The teaching staff has undergone several changes since the academic year of 1941–1942. Arthur F. Greaves-Walker has been called to the colors to serve as Chief of the Non-Metals Section of the War Production Board. Robert L. Stone is acting in the capacity of Department head during Dr. Greaves-Walker's military leave. C. M. Lambe, Jr., former ceramic engineer for the Eljer Co., Ford City, Pa., and a graduate of this Department, has joined the staff as the instructor, replacing J. N. Smith, Jr., who entered the Army last June. W. G. Van Note, professor in the Department of Mechanical Engineering, is aiding materially by teaching courses in drying fundamentals and practice, thermal mineralogy, and refractories. Professor Van Note received his doctorate from the Pennsylvania State College in 1911, where his major was metallurgy and his minor was ceramics.

Because of so many changes in the teaching staff, there has been little chance to do a great deal of research. Two projects, however, are being kept alive, namely, (1) the improvement of ceramic insulators for radio and Radar and (2) the development of a Group 30 pyrophyllite insulating refractory.

MISSOURI SCHOOL OF MINES AND METALLURGY

The Student Branch of the Missouri School of Mines and Metallurgy held its regular meeting on September 29, 1942. The principal feature of the program was the showing of a sound film entitled "The Goose Lake Fire-Clay Deposits," which was loaned to the Student Branch by Otis L. Jones, president of the Illinois Clay Products Co., Joliet, Ill. The students were extremely interested in the various processes shown in the film.

During the business meeting, the Student Branch voted to cooperate in Engineer's Day (held October 24) and also elected a committee to work on issuing the annual Student Branch newspaper.

Refreshments were served after the meeting.

—R. RASMUSSEN, *Secretary-Treasurer*

HEAT-TREATING COURSE AT UNIVERSITY OF ILLINOIS

A short course in "Heat-Treating for Porcelain Enamelers" was held November 2–5, 1942, at the University of Illinois, Urbana, Ill. The course was sponsored by the Porcelain Enamel Institute in cooperation with the Departments of Ceramic Engineering and Mining and Metallurgy at the University of Illinois.

Program Presented

(1) "Components of Steel: (*a*) Iron, (*b*) Iron Carbide, and (*c*) Other Constituents" by H. L. WALKER, professor and head, Dept. of Mining and Metallurgical Engineering.

TESTING

(2) "Strength Tests: (*a*) Yield Strength, (*b*) Ultimate Strength, and (*c*) Hardness; Ductility Tests: (*a*) Elongation, (*b*) Reduction of Area, and (*c*) Ductility; and Miscellaneous Tests: (*a*) Impact, (*b*) Fatigue, and (*c*) Creep" by H. F. MOORE, professor of engineering materials, and W. J. PUTNAM, professor of theoretical and applied mechanics.

HEAT-TREATMENT

(3) "Furnace Atmospheres and Equipment" by W. H. BRUCKNER, research assistant professor of metallurgical engineering.

(4) "(*a*) Full Annealing, (*b*) Normalizing, (*c*) Spheroidizing, and (*d*) Machinability" by H. L. WALKER, professor and head, Dept. of Mining and Metallurgical Engineering.

HEAT-TREATMENT AND EFFECTS

(5) "Change of Physical Properties on Annealing and Normalizing" by W. H. BRUCKNER, research assistant professor of metallurgical engineering.

(6) "Microstructure of Steels as Treated and Tested" by E. J. ECKEL, instructor in metallurgical engineering.

QUENCHING AND TREATING

(7) "Quenching and Tempering" by H. L. WALKER, professor and head, Dept. of Mining and Metallurgical Engineering.

(8) "Austempering and Quenchants" by H. L. WALKER.

(9) "Carburizing and Nitriding" by R. L. COOK, instructor, Dept. of Ceramic Engineering.

HEAT-TREATING METHODS

(10) "Quenching, Tempering, and Hardenability" by E. J. ECKEL, instructor in metallurgical engineering.

(11) "Microscopic Structure Produced by Heat-Treating Steels and Their Interpretation and Correlation with Physical Properties" by B. G. RICKETTS, instructor in metallurgical engineering.

NECROLOGY

ALFRED NELSON FINN

Alfred Nelson Finn, chief of the Glass Section, National Bureau of Standards, Washington, D. C., died at the home of his brother in Lincoln, Neb., on September 21, 1942. He had been seriously ill for about one year.

Biography

Mr. Finn was born in Denver, Colo., on August 10, 1882. After attending grade and high schools in Denver, he went to the University of Denver where he received his B.A. degree in chemistry and physics in 1906 and his M.A. degree in chemistry and mathematics in 1909. He remained at the University as instructor in chemistry until his appointment to the National Bureau of Standards in 1911.

As chemist in the Structural Materials Laboratory of the Bureau, Mr. Finn tested and analyzed cement, paints, oils, varnishes, coated metals, nonferrous alloys, boiler waters, boiler compounds, and protective coatings for metals. He resigned from the National Bureau of Standards in 1919 to become chief chemist and metallurgist for the Hydraulic Steel Co., Cleveland, Ohio. In 1920, he returned to the Bureau to assume the position he held at the time of his death.

During the time he was chief of the Glass Section, the production of optical glass was increased from a few hundred pounds a year up to the point where the production is a substantial part of the glass required for the present war effort. He directed the work in producing the seventy-inch glass disk for the telescope mirror which is now in use at the Ohio Wesleyan University, Delaware, Ohio, and was the author of numerous papers on glass (see accompanying list of publications).

Mr. Finn, a Fellow of The American Ceramic Society, became an associate member of The Society in 1922 and an active member in 1924. Taking an active part in the affairs of the Glass Division, he served as secretary in 1924–1927 and in 1930 and 1936. He was chairman in 1937 and also served on various committees throughout his long association with the Division.

Mr. Finn was also a member of the American Chemical Society, the American Society for Testing Materials, the Optical Society of America, the American Institute of Chemists, and the Washington Academy of Science.

One of the chief pleasures of Mr. Finn was entertaining his professional associates, and his many friends in The American Ceramic Society will remember him as a generous host who seldom was too busy to find time to help make their stay in Washington pleasant.

For a photograph of Mr. Finn, see p. 232, October, 1942, Bulletin.

Publications of A. N. Finn

(1) "Determination of Uranium and Vanadium in Carnotite Ores," *Jour. Amer. Chem. Soc.*, **28** (1906).

(2) (With R. J. Wig and G. M. Williams) "Durability of Cement Drain Tile and Concrete in Alkali Soils," *Bur. Stand. Jour. Research Tech. Paper*, No. 95, 94 pp. (Nov. 15, 1917).

(3) (With H. S. Rawdon and M. S. Grossmann) "Metallic Coatings for Rust-Proofing Iron and Steel," *Chem. & Met. Eng.*, **26** (1919).

(4) (With P. D. Merica and R. G. Waltenberg) "Mechanical Properties and Resistance to Corrosion of Rolled Light Alloys of Aluminum and Magnesium with Copper, Nickel, and Manganese," *Bull. Amer. Inst. Mining Met. Engrs.*, (1919).

(5) (With R. F. Geller) "Further Studies on Cast Glass Pots," *Jour. Amer. Ceram. Soc.*, **6** [8] 865-72 (1923).

(6) (With H. G. Thomson) "Density and Index of Refraction of Glass versus Its Composition," *ibid.*, **8** [8] 505–13 (1925).

(7) "Describes 'Strain' in Glass," *Nat. Glass Budget*, **42** [21] 8 (1926).

(8) "Specifications and Physical Tests for Table Chinaware; Their Meaning to the Producer and User," *Ceramist*, **8** [5] 330–37 (1926).

(9) "Cobalt-Blue Glass with Cerium Oxide Excludes Actinic Rays of Light," *Nat. Glass Budget*, **42** [27] 17 (1926).

(10) (With W. W. Coblentz) "A Non-Actinic Cobalt-Blue Glass," *Jour. Amer. Ceram. Soc.*, **9** [7] 423–25 (1926).

(11) "The Annealing of Glass, a Nontechnical Presentation," *ibid.*, [8] 493–500.

(12) (With L. W. Tilton and A. Q. Tool) "Some Effects of Carefully Annealing Optical Glass," *ibid.*, **11** [5] 292–95 (1928).

(13) (With L. W. Tilton and A. Q. Tool) "Cause and Removal of Certain Heterogeneities in Glass," *Bur. Stand. Jour. Research Sci. Paper*, No. 572 (1928).

(14) "Making the Glass Disk for a 70-Inch Telescope Reflector," *Bur. Stand. Jour. Research*, **3** [2] 315–29 (1929); R.P. 97; *Nat. Glass Budget*, **45** [19] 8 (1929).

(15) (With J. F. Klekotka) "A Modified Method for Decomposing Aluminous Silicates for Chemical Analysis," *Bur. Stand. Jour. Research*, **4** [6] 809–13 (1930); *Ceram. Age*, **16** [3] 158–59 (1930).

(16) (With C. A. Faick) "The Index of Refraction of Some Soda-Lime-Silica Glasses as a Function of the Composition," *Jour. Amer. Ceram. Soc.*, **14** [7] 518–28 (1931); *Bur. Stand. Jour. Research*, **6** [6] 993–1002 (1931); R.P. 320.

(17) (With B. C. Schmid and J. C. Young), "Thermal Expansions of Soda-Lime-Silica Glasses as Functions of Composition," *Bur. Stand. Jour. Research*, **12** [4] 421–28 (1934).

(18) (With C. A. Faick, J. C. Young, and Donald Hubbard) "Index of Refraction, Density, and Thermal Expansion of Soda-Alumina-Silica Glasses as Functions of Composition," *Jour. Research Nat. Bur. Standards*, **14** [2] 133–37 (1935); R.P. 762; *Glass Ind.*, **16** [3] 81–83 (1935).

(19) (With F. W. Glaze) "Routine Determination of Boron in Glass," *Jour. Research Nat. Bur. Standards*, **16** [5] 421–29 (1936); R.P. 882.

(20) (With Clarence Hahner and G. Q. Voigt) "Gases in Optical Glasses, etc.," *ibid.*, **19** [1] 95–103 (1937); R.P. 1014.

(21) "Optical Glass at National Bureau of Standards," *Jour. Optical Soc. Amer.*, **28**, 13–17 (1938).

(22) "Potash in Glass Industry," *Ind. Eng. Chem.*, **30** [8] 891–92 (1938).

(23) (With Donald Hubbard and E. H. Hamilton) "Effect of Solubility of Glass on Behavior of the Glass Electrode," *Jour. Research Nat. Bur. Standards*, **22** [3] 339–49 (1939); R.P. 1187.

(24) (With J. C. Young, F. W. Glaze, and C. A. Faick) "Density of Soda-Potash-Silica Glasses as Function of Composition," *ibid.*, [4] 453–64.

(25) (With J. C. Young) "Effect of Composition and Other Factors on Specific Refraction and Dispersion of Glasses," *Jour. Research Nat. Bur. Standards*, **25** [6] 759–82 (1940); R.P. 1352.

(26) (With Edward Wichers and W. S. Clabaugh) "Comparative Tests of Chemical Glassware," *ibid.*, **26** [6] 537–56 (1941); R.P. 1394.

(27) (With F. W. Glaze) "Improvement in 'Partition Method' for Determination of Boron," *ibid.*, **27** [1] 33–37 (1941); R.P. 1401.

(28) (With J. C. Young) "Comparison of Two Studies on Refraction and Dispersion of Glasses," *Jour. Optical Soc. Amer.*, **31**, 383–84 (1941).

S. R. Scholes Expresses Sentiments of Fellow Glassmen in Letter to Editor

The news has just reached us that A. N. Finn died at Lincoln, Neb., September 21.

We all knew, of course, that his health was ruined and that he had been incapacitated for the past year or more, but most of us had hoped that he might yet recover.

This is not only the first break in the ranks of the "old guard" of the Glass Division in a long time, but it is a death that means a distinct loss to the National Bureau of Standards and to the whole world of glass technology. This is particularly true of the field of optical glass, where, I think, Finn was a real authority.

He had a genuine zeal for accuracy that we would all do well to acquire. He seemed to be much less interested in the publication of papers than in finding out the truth.

If he ever appeared to me to be intolerant, I could always recognize that his intolerance was not directed at persons, but at findings that were less than the best that could be found and at theorizing that had no sound basis in fact.

We shall miss him sadly in the meetings and councils of the Division. Even though we did not see him for months at a time, we shall miss the feeling that he was always there in Washington, giving his leadership to creative work.

—Samuel R. Scholes,
Secretary, Glass Division

MRS. HEINRICH RIES

Mrs. Heinrich Ries, the wife of Heinrich Ries, professor of geology at Cornell University, Ithaca, N. Y., died at her home in Ithaca on October 8.

Mrs. Ries had attained considerable distinction for her work as a botanical artist. Among other achievements, she had illustrated a botanical encyclopedia when she was employed at the Bronx Botanical Gardens in New York City.

Mrs. Ries is survived by her husband and one son, Victor H. Ries, a professor in the Department of Horticulture, Ohio State University, Columbus, Ohio.

C. G. GUIGNARD

C. G. Guignard, president and manager of the Guignard Brick Works, Columbia, S. C., since 1929, died December 19, 1941.

Mr. Guignard became seriously ill in May, 1941, and submitted to several serious operations. After apparently recuperating, he became ill again in the fall and failed to rally.

Mr. Guignard had been a member of The American Ceramic Society since 1937.

EDWARD MATHEWS AYERS

Edward Mathews Ayers, one of the foremost industrialists of Zanesville, Ohio, died on October 2, 1942, at his home in Zanesville. He was seventy-nine years old. His death followed an illness of thirteen weeks and came as a great shock to his countless friends and business associates who had hoped that he might be restored to his accustomed vigor.

At the time of his death, Mr. Ayers was president of the Ayers Mineral Company, the Millwood Sand Company, and the Central Silica Company, all located in or near Zanesville.

A biographical sketch of Mr. Ayers was published in *Bull. Amer. Ceram. Soc.*, **21** [4] 50 (1942).

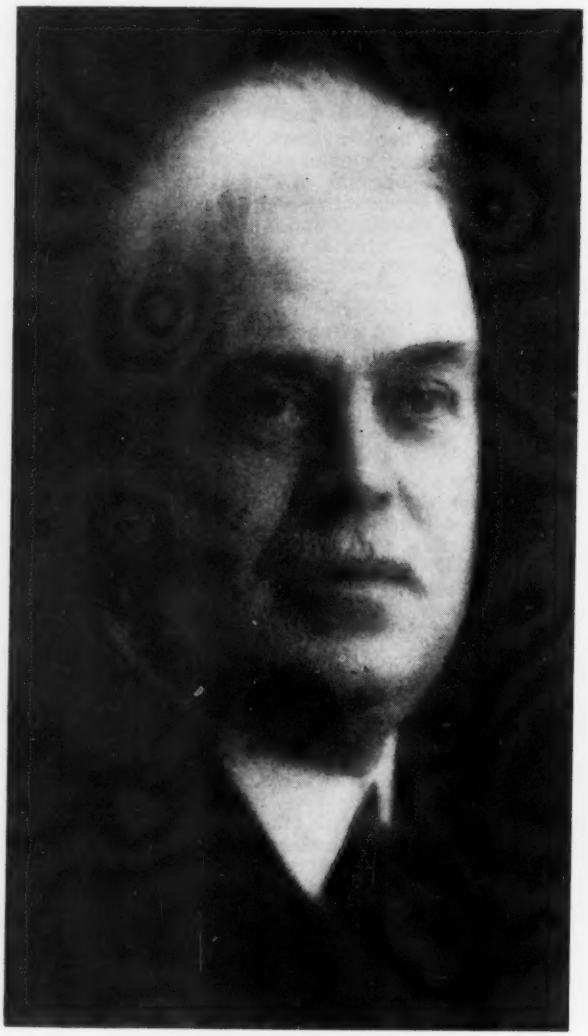
WILLIAM MATHIASEN

William Mathiasen, vice-president and director of the Federal Seaboard Terra Cotta Corp., Perth Amboy, N. J., died August 27 at his home in Westfield, N. J., after a long illness.

Mr. Mathiasen was born in Perth Amboy, N. J., August 18, 1875. A pioneer in the terra-cotta industry, he was one of the original founders of the South Amboy Terra Cotta Company, which later merged into the Federal Seaboard Terra Cotta Corporation. He was active in this industry up to the time of his illness.

Mr. Mathiasen was for many years a resident of Perth Amboy, where he was active in church affairs as a member and trustee of the St. Stephen's Danish Lutheran Church. He had lived in Westfield for the past twenty-three years, where he was a vestryman of St. Paul's Episcopal Church.

In addition to his association with the Federal Seaboard



William Mathiasen

Terra Cotta Corporation, Mr. Mathiasen was vice-president and director of the Mathol Investment Company of Perth Amboy.

He is survived by his widow; a daughter, Mrs. Carla M. Fenton; and two sons, Harvey R. and Allan C. Mathiasen.

ARTHUR P. TAYLOR

Arthur P. Taylor, president of the Charles Taylor Sons Co., Cincinnati, Ohio, died on October 15, 1942.

NOTES FOR CERAMISTS

OHIO CERAMIC INDUSTRIES ASSOCIATION

The Ohio Ceramic Industries Association held its annual meeting at the Engineering Experiment Station, Ohio State University, Columbus, Ohio, November 6 and 7, 1942.

The following program was presented:

(1) "Present Status of Ceramic Research" by GEORGE A. BOLE, Director of Ceramic Research, Engineering Expt. Sta., Ohio State Univ., Columbus, Ohio.

(2) "Industry and the Salvage Problem as a War Measure" by CLAYTON GRANDY, Trade Association Director, Industrial Salvage Section, Conservation Div., War Production Board, Washington, D. C.

(3) "The Selective Service System and Industry" by COLONEL FURMAN G. SPENCER, Chief, Occupational Advisor of the Ohio Selective Service System, Columbus, Ohio.

(4) "The Ceramic Raw Materials Situation—Priorities and Deliveries" by ARTHUR F. GREAVES-WALKER, Chief, Non-Metals Section, War Production Board, Washington, D. C.

(5) "What the Ceramic Industry Can Do in the Way of Substitute Materials and Products" by J. B. SHAW, Industrial Consultant, Ceramic Products, War Production Board, Washington, D. C.

(6) "What the Ohio State University Is Doing in Special Training of Personnel for the War Industries" by H. E. NOLD, Director, Engineering, Science, and Management War Training, Ohio State University, Columbus, Ohio.

A buffet luncheon was served Saturday noon after the annual business meeting which ended the program. In the afternoon, members attended the Ohio State-Pittsburgh football game.

Reception for American Ceramic Society President

Members of the Association were guests at a reception held Friday evening at the executive offices of The American Ceramic Society in honor of Louis J. Trostel, president of The Society. Refreshments were served.

INDUSTRIAL HYGIENE FOUNDATION

The seventh annual meeting of the Industrial Hygiene Foundation, the organization's first wartime conference, was held at Mellon Institute, Pittsburgh, Pa., November 10 and 11. The program, geared to guard the health of war workers, developed practical, how-to-do-it data for saving manpower lost through illness.

The following subjects were discussed during the meeting sessions: (1) more manpower through the reduction of absences; (2) the safeguarding of women workers, older men, and physically handicapped persons; (3) fatigue, including hours of work, rotation of shifts, and nutrition; (4) health data on grinding wheels, magnesium dust, and aluminum powder to combat silicosis; (5) industrial health problems in chemical industries; (6) findings from Foundation researches (medical and engineering); and (7) legal developments and trends (precautions prevent claims).

CERAMICENTER

The Ceramicenter, 17 West 57th St., New York, N. Y., which held its grand opening on April 7, 1942, is an organization established (1) as a clearing house for ceramic artists, designers, and sculptors who are prepared to meet the existing requirements of the present commercial markets, (2) to benefit our native craftsmen, (3) to promote the ceramic industry in America, and (4) to stimulate the ceramic industry in America to a better artistic conception.

The Ceramicenter carries all types of fine examples of utilitarian and decorative ceramics such as ceramic jewelry, gift pieces, porcelains, stoneware, pottery, earthenware, china, tile, terra cotta, glass, kitchen accessories, and cosmetic containers. Original pieces are factory-reproduced in large quantities or artist-produced in limited quantities.

Outlets for the Ceramicenter are department stores, gift shops, decorators and architects, original pieces (retail), and chain stores.

Special Advantages to Buyers

(1) Latest designs created by leading American artists and sculptors; (2) an information service for buyers of ceramics; (3) a weekly bulletin containing timely information about buyers' exacting requirements, artists' specialized skills, etc.; (4) a laboratory service for finishes, decoration, and form to meet specific needs; (5) a free consultation service on various problems; and (6) the execution of special orders for limited editions, confined lines, or large quantities.

Special Advantages to Artists

(1) A permanent exhibition space at the Ceramicenter, which is located in the art center of the world and which is visited by buyers from everywhere; (2) a current list of buyers' requirements which artists may consult at any time; (3) a large volume of free and unusual publicity—press, trade periodicals, magazines, and radio; (4) the negotiation of business transactions; (5) participation in gift shows; (6) a list of factories qualified to reproduce artists' pieces at highest standard and best price levels; and (7) an excellent staff photographer who will quote special rates to Ceramicenter artists.

Enlargement of Artists' Scope

An advisory board of qualified specialists serves in the following categories: (1) merit from the standpoint of high-standard ceramic art; (2) suitability for mass production; (3) sales appeal and price levels; (4) business viewpoint; and (5) information relative to materials, their sources, and all other pertinent facts. Association with ceramic societies will provide a medium for the exchange of ideas and interests with other craftsmen. Educational activities at the Ceramicenter include demonstrations, such as the artist at the wheel, illustrated lectures, motion pictures, individual and group exhibits at art galleries, museums, and other places of art interest.

Commercial Protection of Artists

Fixed prices will be determined on plaster models and designs sold outright. Fixed price levels will be maintained on quantity sales varying in price according to the number of pieces sold. The Ceramicenter will (1) receive 20% of the sale price on each piece produced by the artist sold wholesale; (2) receive 33⅓% on original pieces sold directly from the floor; and (3) work on a royalty basis on large-quantity distribution if so desired by the artist, the artist supplying the plaster model, finished piece, and mold. The Ceramicenter will arrange for the manufacturing of such pieces.

High-standard ceramic art will be maintained and exhibited only upon the approval of a qualified board.

As a result of its policy and service, the Ceramicenter brings about a closer relationship and collaboration between artist, manufacturer, and buyer in an endeavor to promote the appreciation and practice of ceramic art in America.

NEW YORK SOCIETY OF CERAMIC ARTS

The New York Society of Ceramic Arts held its Forty-Second Annual Meeting and exhibition at the Metropolitan Museum of Art, 5th Ave. at 82d St., from November 4 to 12, inclusive. This exhibition was open to all forms of American ceramic art, including pottery, tile, terra cotta or sculpture, glass, stained glass, and enameled metal.

CORUNDUM SEARCH ON IN NORTH CAROLINA

North Carolina geologists have undertaken a survey to locate deposits of corundum at the request of the War Production Board, which urged that information be made available at the earliest possible time.

Corundum is an abrasive next to the diamond in hardness and formerly was mined in this State. Large-scale importation of corundum and emery from abroad and the development of silicon carbide and other substitutes forced the closure of all mines in 1918.

With the exception of a few localities scattered in Montana, Colorado, Idaho, and California, all of the corundum known in the United States is in the Appalachian region. North Carolina is better supplied with corundum than any other state; there are more than sixty localities where it is known. The commercial deposits so far have been worked in four counties, Clay, Macon, Jackson, and Transylvania, all in extreme western North Carolina.

Working in cooperation with the Tennessee Valley Authority, the North Carolina Department of Conservation and Development is making a study of abandoned workings and other deposits.

NEW USES FOR VERMICULITE

The huge new War Department building in Washington will be protected from incendiary bombs by North Carolina vermiculite, a little-known mineral which is becoming an important factor in modern warfare.

The vermiculite has been ordered from the Bee Tree Mines, near Asheville, which already have supplied thousands of tons of the mineral to make bombproof decks for military installations. Because of these uses and the rapid discovery of other uses, vermiculite production in North Carolina (where all the mineral in the East is located) is proceeding at a record rate, with new deposits being opened.

Vermiculite has the peculiar quality of exfoliation with intense heat. Treated thus, the expansion is so great that untreated mineral weighing 100 lb. per cu. ft. will weigh only 6 to 20 lb. per cu. ft. after heating. It is also highly fire-resistant and mixed with concrete provides both lightness and insulation. When vermiculite is used as an aggregate in concrete, the precast slabs can be sawed, nailed, and worked much like wood.

Because of its lightness when treated, vermiculite is also being used for packing shells and bombs for shipment to the front and for filling life preservers as a substitute for cork. Experiments are now under way to use it as a filter for aviation gasoline to replace the various earths now scarce.

The peculiar properties of vermiculite indicate many widespread peacetime uses. Experiments have been made in using lightweight concrete for prefabricated houses, and its use as an insulator was already under way before the war. It can also be used in making heat-insulating brick and in fireproof plasters.

The lubricating qualities of vermiculite are comparable to those of flake graphite. Used as an extender for aluminum paints, it increases coverage by 25% and is now being used both as a coolant and lubricating agent in automobile motors and transmissions. Other uses are being constantly reported, with many interesting possibilities, especially in construction.

The vermiculite reserves in North Carolina total between 300,000 and 440,000 tons. They occur principally in Avery, Buncombe, Clay, Jackson, and Macon counties.

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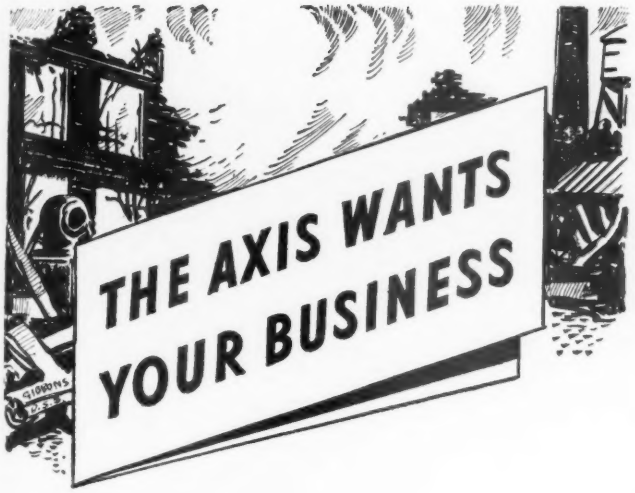

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Thomas Alabama Kaolin Co.

Clay (Wall Tile)
Hammill & Gillespie, Inc.
Kentucky Clay Mining Co.
Maxson, Elwyn L.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.

Cleaners
Pennsylvania Salt Mfg. Co.
Porcelain Enamel and Mfg. Co.

Cleaners, Chemical
Harshaw Chemical Co.
Pennsylvania Salt Mfg. Co.

Clocks (Gauge Board)
The Hommel, O., Co., Inc.

Cobalt Oxide
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Cobalt Sulphate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Colors
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Cone Plaques
Industrial Ceramic Products, Inc.

Cones
The Edward Orton, Jr., Ceramic Foundation

Conveying Equipment
Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.
National Engineering Co.

Copper Oxide
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Corhart
Corhart Refractories Co.

Cornwall Stone (Imported)
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.

Crucibles (Filter, Melting, Ignition)
Carborundum Co.
Denver Fire Clay Co.
Norton Co.
Potters Supply Co.

Crushers (Clay)
Lancaster Iron Works, Inc.

Cryolite (see Kryolith)
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.
The Vitro Mfg. Co.

Crystolon (Refractory Products)
Norton Co.

Cullet, Washing Plants, Incinerators, Crushers
Frazier-Simplex, Inc.

Cutters (Bar)
Industrial Ceramic Products, Inc.

Decorating Supplies
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Disintegrators
Lancaster Iron Works, Inc.
National Engineering Co.

Dryer (Pipe Rack)
Lancaster Iron Works, Inc.

Drying Machinery
Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.
Proctor & Schwartz, Inc.

Electrocast Refractories
Corhart Refractories Co.

Enamelers' Borax
Porcelain Enamel and Mfg. Co.

Enameling Equipment (Complete)
Frazier-Simplex, Inc.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Enameling Furnaces
Carborundum Co.
The Hommel, O., Co., Inc.
Lancaster Iron Works, Inc.
Norton Co.

Enameling Iron (Sheet)
American Rolling Mill Co.

Enameling Muffles
Carborundum Co. (*Carbofrax*)
Frazier-Simplex, Inc.
Norton Co. (*Alundum*)

Enameling (Practical Service)
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Enamels
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Enamel Oxide
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.

Enamels (Porcelain)
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Equipment (Porcelain Enameling)
The Hommel, O., Co., Inc.

Feldspar
Du Pont de Nemours, E. I., & Co., Inc. Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Filter Fabrics
Metakloth Company

Fire Brick
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Norton Co.

Fire Brick—Process Equipment
Lancaster Iron Works, Inc.

Fire Clay
Denver Fire Clay Co.
Great Lakes Foundry Sand Co.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.

Firing Control System
Forester Firing System

Flint
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Great Lakes Foundry Sand Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Porcelain Enamel and Mfg. Co.

Flint Pebbles
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Floors (Non-Slip)
Norton Co.

Fluorspar
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

French Flint
Maxson, Elwyn L.

Frit
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Frosting Mixtures
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Fuel Oil Systems and Control, Stokers
Frazier-Simplex, Inc.

Furnaces
Carborundum Co. (*Carboradiant*)
Denver Fire Clay Co.
Frazier-Simplex, Inc.
The Hommel, O., Co., Inc.
Swindell-Dressler Corp.

Furnaces, Enameling
Swindell-Dressler Corp.

Glass Bending Ovens, Glass Decorating Machines
Frazier-Simplex, Inc.

Glass Equipment
Lancaster Iron Works, Inc.

Glass Melting Tanks and Furnaces
Frazier-Simplex, Inc.

Glass Sand
Great Lakes Foundry Sand Co.

Glass Thickness Gauge
Bausch & Lomb Optical Co.

Glaze and Body Spar
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Glazes and Enamels
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Glaze Spar
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.

Goggles
The Hommel, O., Co., Inc.

Gold
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Gold Decorations
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
The Hommel, O., Co., Inc.

Granulators
Lancaster Iron Works, Inc.

INDUSTRIAL CERAMIC PRODUCTS, Inc.

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All Types of Circular and Straight Tunnel Kilns

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2412 Ken Oak Road, Baltimore, Md.

Mines: Chalk Bluff, Ala. Processing Plant: Heckleburg, Ala.

Analysis

Loss on ignition	13.89%
Silica (SiO_2)	44.74
Aluminum oxide (Al_2O_3)	39.47
Titanium oxide (TiO_2)	1.29
Ferric oxide (Fe_2O_3)	0.55
Lime (CaO)	0.00
Magnesia (MgO)	0.00
Alkalis (Na_2O, K_2O)	0.00

Mechanical Composition

—20 microns	98.00%
—10 "	80.98
— 6 "	70.94
— 3 "	54.70
— 1 "	37.74
— 0.5 "	21.75

The Best West of the Rockies

- **POTTERY CLAYS**
  English and American
- **CERAMIC COLORS**
  Blythe Colour Works, Ltd.
- **SLABS...SETTERS...SAGGERS**
  New Castle Refractories Co.
- **STANDARD PYROMETRIC CONES**
  Edward Orton, Jr., Ceramic Foundation
- **FRANTZ FERROFILTERS**
- **LAKEFIELD NEPHELINE SYENITE**
  Great Lakes Foundry Sand Co.

ELWYN L. MAXSON

112 W. 9TH ST. *Ceramic Materials* LOS ANGELES

Grinding Wheels
Carborundum Co. (*Carborundum and Aloxite*)
Electro Refractories & Alloys Corp.
Norton Co. (*Alundum-Crystolon*)

Hearths
Carborundum Co. (*Carbofrax* heat treating)
Corhart Refractories Co.
Norton Co. (*Crystolon*)

Hearths (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.
Norton Co.

Hydrofluoric Acid
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Iron Chromite
Harshaw Chemical Co.

Iron (Enameling)
American Rolling Mill Co.

Iron Oxide
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Foote Mineral Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Kaolin
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Thomas Alabama Kaolin Co.
The Vitro Mfg. Co.

Kilns, China (Decorating)
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Frazier-Simplex, Inc.
The Hommel, O., Co., Inc.
Swindell-Dressler Corp.

Kilns (Electric, Circular, Tunnel)
Swindell-Dressler Corp.

Kiln Furniture (Silicon Carbide, Semi-Silicon Carbide) (Refractory)
Carborundum Co.
Electro Refractories & Alloys Corp.
Louthan Mfg. Co.

Kryolith (see Cryolite)
Pennsylvania Salt Mfg. Co.

Laboratory Ware
Norton Co.

Lehr Tile (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.
Electro Refractories & Alloys Corp.

Lehrs
Frazier-Simplex, Inc.
Swindell-Dressler Corp.

Lehrs (Electric or Fuel Heated)
Frazier-Simplex, Inc.
Swindell-Dressler Corp.

Lehr Loaders
Frazier-Simplex, Inc.

Linings (Furnace Refractory, Block Refractory Plate, Brick, and Tile)
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Norton Co.
The Vitro Mfg. Co.

Lithium Carbonate
Drakenfeld, B. F., & Co.
Foote Mineral Co.

Lithium Minerals
Foote Mineral Co.

Loaders (Bucket)
National Engineering Co.

Magnesia (Fused)
Electro Refractories & Alloys Corp.
Norton Co.

Magnesia (Sintered, Calcined)
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.

Magnesite
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Foote Mineral Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Magnesite Calcined
Foote Mineral Co.
The Hommel, O., Co., Inc.

Magnesium Carbonate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Manganese
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Manganese Dioxide
Drakenfeld, B. F., & Co.
Foote Mineral Co.

Manganese (Oxide)
Corhart Refractories Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Masks (Breathing)
Drakenfeld, B. F., & Co.

Metals (Porcelain Enameling)
American Rolling Mill Co.

Micronized Products
Porcelain Enamel and Mfg. Co.

Microscopes (Polarizing)
Bausch & Lomb Optical Co.

Microscopes (Stereoscopic)
Bausch & Lomb Optical Co.

Minerals
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Foote Mineral Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Mixers
National Engineering Co.

Mixers (Batch)
Lancaster Iron Works, Inc.
National Engineering Co.

Mixers (Concrete, Paving, Road Paving, Plaster, Asphalt, Truck, Mortar, Bituminous)
Lancaster Iron Works, Inc.

Mixers (Laboratory)
Lancaster Iron Works, Inc.
National Engineering Co.

Mold Sanders
Lancaster Iron Works, Inc.

Muffles (Furnace) (Laboratory)
Carborundum Co. (*Carbofrax*)
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Frazier-Simplex, Inc.
Norton Co.

Mullers (Batch)
Lancaster Iron Works, Inc.
National Engineering Co.

Muriatic Acid
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.

Needle Antimony
Foote Mineral Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Nepheline Syenite
Great Lakes Foundry Sand Co.

Nickel Salts
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Nitrates (Cobalt, Sodium)
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc. Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Nitre
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Norbide (Norton Boron Carbide)
Norton Co.

Olivine
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.

Opacifiers
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc. Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Pennsylvania Salt Mfg. Co.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Overglaze Colors
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.

Oxides
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Palladium Decorations
Du Pont de Nemours, E. I., & Co., Inc. Electrochemicals Dept.
The Hommel, O., Co., Inc.

Pins
The Hommel, O., Co., Inc.
Industrial Ceramic Products, Inc.
Louthan Mfg. Co.
Potters Supply Co.

Pins (Tile Setter)
Louthan Mfg. Co.

Placing Sand
Great Lakes Foundry Sand Co.

Platinum Decorations
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
The Hommel, O., Co., Inc.

Polariscopes
Bausch & Lomb Optical Co.
Frazier-Simplex, Inc.

Porcelain Enameling Service (Practical)
American Rolling Mill Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Porcelain Enamels
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Potters Wheels
Denver Fire Clay Co.

Potash (Carbonate)
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Solvay Sales Corp.
The Vitro Mfg. Co.

Producer Glass Plants
Frazier-Simplex, Inc.

Pug Mills
Lancaster Iron Works, Inc.

Pyrites (Natural Iron Sulphide)
Foote Mineral Co.
The Hommel, O., Co., Inc.

Pyrometer Tubes
Carborundum Co.

Pyrometer Tubes (Refractory and Hard Porcelain)
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
McDanel Refractory Porcelain Co.
Norton Co.
Charles Taylor Sons Co.

Pyrometers (Optical, Radiation, Surface, Immersion, Needle)
Leeds & Northrup Co.

Pyrometric Cones
The Edward Orton, Jr., Ceramic Foundation

Racks, Firing (Refractory)
Louthan Mfg. Co.

Raw Material Handling Equipment
Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.

Refractometers
Bausch & Lomb Optical Co.
Electro Refractories & Alloys Corp.

Refractories
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co
Electro Refractories & Alloys Corp.
Louthan Mfg. Co.
Norton Co.

Refractory Materials
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Green, A. P., Fire Brick Co.
Louthan Mfg. Co.
Norton Co.
Charles Taylor Sons Co.
Thomas Alabama Kaolin Co.
Titanium Alloy & Mfg. Co.

Respirators
Drakenfeld, B. F., & Co.
The Hommel, O., Co., Inc.

Rutile
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Foote Mineral Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Saggers
Carborundum Co.
Electro Refractories & Alloys Corp.
Norton Co.
Potters Supply Co.

Salt Cake
American Potash & Chemical Corp.
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.

Sandblast Sand
Great Lakes Foundry Sand Co.

Sand Grinder and Sifters
Lancaster Iron Works, Inc.

Saponin
The Hommel, O., Co., Inc.

Screening and Magnetic Separators
National Engineering Co.

Selenite of Sodium
Drakenfeld, B. F., & Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Selenium
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Foote Mineral Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Setters (Tableware)
Louthan Mfg. Co.

Sheets (Enameling Iron)
American Rolling Mill Co.

Silica (Fused)
Electro Refractories & Alloys Corp.
Foote Mineral Co.
The Hommel, O., Co., Inc.

Silicate of Soda
Ceramic Color & Chemical Mfg Co.
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Silicon Carbide
Carborundum Co.
Electro Refractories & Alloys Corp.
Norton Co.

Silicon Carbide Firesand
Carborundum Co.

Sillimanite Refractories
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.

Slabs (Furnace)
Carborundum Co.
Electro Refractories & Alloys Corp.
Norton Co.

Soda Ash
American Potash & Chemical Corp.
Denver Fire Clay Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.
Solvay Sales Corp.
The Vitro Mfg. Co.

Sodium Antimonate
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Sodium Fluoride
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Sodium Metasilicate
Harshaw Chemical Co.

Sodium Nitrite
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Sodium Silica Fluoride
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Sodium Uranate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Soot Blowers
Frazier-Simplex, Inc.

Special Machines
Frazier-Simplex, Inc.

Spar
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
The Vitro Mfg. Co.

Spray Booths
The Hommel, O., Co., Inc.

Spraying Equipment
The Hommel, O., Co., Inc.

Spurs
Louthan Mfg. Co.
Potters Supply Co.

Stacks
Lancaster Iron Works, Inc.

Steel Plate Construction
Lancaster Iron Works, Inc.

Stilts
The Hommel, O., Co., Inc.
Industrial Ceramic Products, Inc.
Louthan Mfg. Co.
Potters Supply Co.

Sulfur
Stauffer Chemical Co.

Sulfuric Acid
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.
Stauffer Chemical Co.

Talc
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
International Pulp Company

Tanks
Frazier-Simplex, Inc.

Tank Blocks
Corhart Refractories Co.

Tanks (Pickle)
The Hommel, O., Co., Inc.

Tanks for Raw Material Steel or Concrete
Lancaster Iron Works, Inc.

Tile (Floor)
Norton Co.

Tile (Muffle)
Carborundum Co.
Electro Refractories & Alloys Corp.
Norton Co.

Tile Setter Pins
Louthan Mfg. Co.

Tile (Refractory)
Carborundum Co. (*Carbofrax*)
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Norton Co.
Thomas Alabama Kaolin Co.

Tile (Wall)
Denver Fire Clay Co.
Thomas Alabama Kaolin Co.

Tin Oxide
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Titanium
Drakenfeld, B. F., & Co.
Foote Mineral Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Titanium Oxide
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Foote Mineral Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Trisodium Phosphate
Harshaw Chemical Co.

Trucks
Lancaster Iron Works, Inc.

Tubes (Insulating)
Carborundum Co.
Louthan Mfg. Co.
McDanel Refractory Porcelain Co.
Norton Co.

Tubes (Pyrometer)
Carborundum Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
McDanel Refractory Porcelain Co.
Norton Co.

Uranium Oxide
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Uranium Oxide (Yellow-Orange-Black)
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Water Softening Plants
Frazier-Simplex, Inc.

Wet Enamel
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Whiting
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Winding Drums
Lancaster Iron Works, Inc.

Zinc Oxide
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Zircon
Foote Mineral Co.
The Hommel, O., Co., Inc.

Zirconia
Du Pont de Nemours, E. I., & Co., Inc., Electrochemicals Dept.
Foote Mineral Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Titanium Alloy & Mfg. Co.
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Zirconium Oxide
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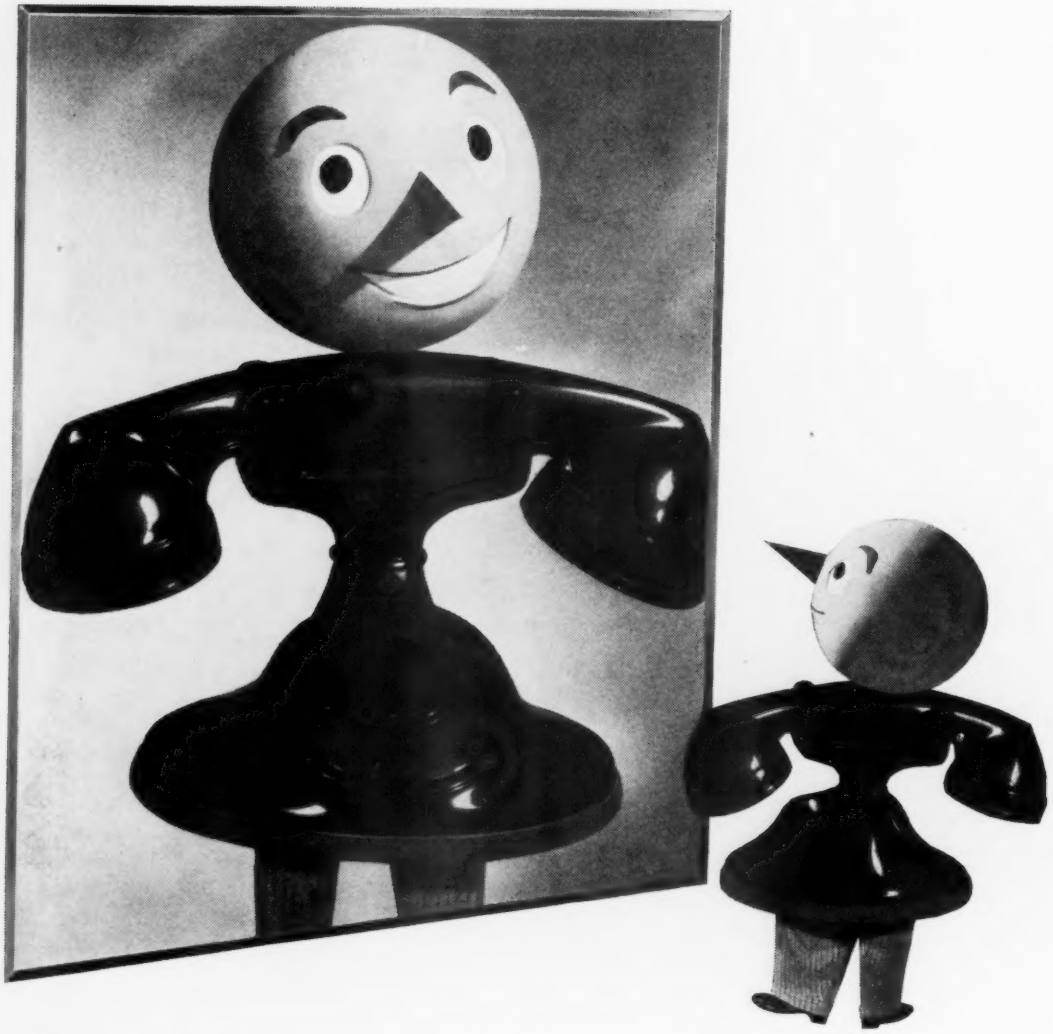

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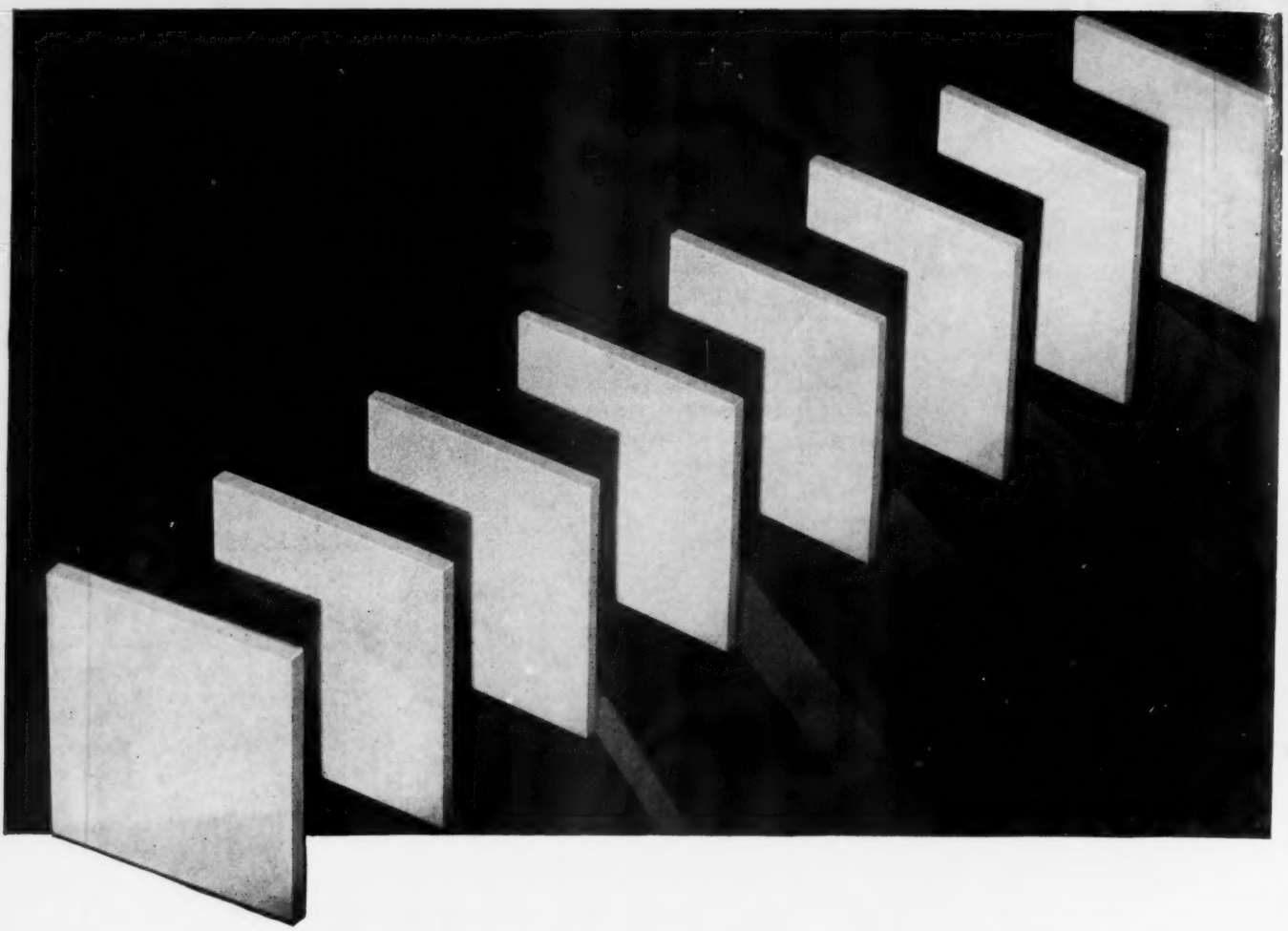

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